TEACHING OF SCIENTIFIC INVESTIGATIONS BY LIFE AND NATURAL SCIENCE EDUCATORS IN BUSHBUCKRIDGE

by

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DECLARATION

I, Amos Paspas Dlamini, declare that the "***Teaching of Scientific Investigations by Life and Natural Science Educators in Bushbuckridge***" is my own work and has not been submitted in any institution. All the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

Mr Dlamini A.P. Date

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Lastly, the Almighty God, who is my strength and source of energy.

DEDICATION

I dedicate my dissertation to my wife, Eugy, Asante, my child; my mother Ntombane, my uncle Hlekani and the late Sesi Olga Dlamini-Mnisi and the entire Mbhay' mbhay clan.

ABSTRACT

The study describes the teaching of scientific investigations by Life and Natural Sciences educators in the Bushbuckridge Region in Mpumalanga Province, South Africa. A quantitative survey method was exploited using a Cluster sampling method. The study was conducted a year after the introduction of the National Curriculum Statement in Grade 10, in South African schools. The study found that most educators use teacher-centred teaching methodologies rather than open inquiry in teaching scientific investigations. Schools still have a shortage of infrastructure, teaching resources and references, which make it difficult for the educators to shift towards the expected new system of teaching. Teachers are confronted with language barriers, heavy workload and insufficient retraining in the new curriculum.

Key words

Science process skills, inquiry instruction, basic science process skills, integrated science process skills, cookbook inquiry, directed inquiry, open inquiry, guided inquiry, cooperative instruction, problem based learning, scientific investigations and experimenting.

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ORIENTATION

1.1 INTRODUCTION

Science is considered to be among the requirements for creating wealth and improving the quality of life in every nation (Muwanga-Zake, 2002:01). As Roth and Roychoudhury (1996:128) put it, “the task of science education is to help learners develop critical thinking skills, problem solving skills, willingness to explore new ideas and the development of a critical mind”. As such, the development of the curriculum must match these expectations.

In South Africa, the transformation of the country’s curriculum was initiated to match technological needs and developing learners’ skills to survive in this age. This was evident with the introduction of the then Curriculum 2005, subsequently the Revised National Curriculum Statement (RNCS), and now the National Curriculum Statement (NCS). The new curriculum has to be delivered through the Outcomes Based Education. The curriculum before Curriculum 2005, which was known as nated 550, was rejected because its instructional methodology was outdated, and had been created to divide the country along racial grounds, focused mainly on content acquisition, put very little emphasis on the acquisition of science process skills and scientific investigations (Rambuda, 2003).

The introduction of the new curriculum has impacted on the teaching of science in our schools and, as such, all South African schools are expected to follow the same curriculum, contrary to the directives of the former apartheid education system divided between Blacks and Whites. The teaching of science process skills is now given priority in the curriculum and they must be developed and used in a variety of settings (Department of Education, 2002).

In this age, learners should be afforded an opportunity to use acquired science process skills to investigate the world around them in order to pose questions, solve problems and understand procedures that scientists use in their professional life (Windschitl, 2000:81). Learners should use process skills to investigate phenomena related to the Natural Science and be able to use these skills to solve problems creatively in a scientific context (Department of Education, 2002:8). Learners need to be developed in the area of critical thinking and problem solving. They should develop an understanding of the nature of science (Department of Education, 2003:9).

Understanding the nature of science is advocated as the desired outcome of science teaching and the teaching of science process skills in particular (Tairab, 2001:81; & Department of Education, 2003:9). However, the educators' understanding of science process skills and science teaching will influence what they do in the class. Hence, some educationists believe that educators who do not have proper understanding of process skills will not be able to teach process skills appropriately (Lee, 1993:626).

Inquiry–centered instruction in teaching scientific investigations has never been a smooth path. Hofstein, Shore, and Kipnis (2004) identified the following challenges of teaching through Inquiry orientated curriculum:

- ✓ It requires plenty of time to implement and monitor learning;
- ✓ Teachers need to be professionally trained to use Inquiry centred instruction and being able to teach scientific investigations;
- ✓ Requires relevant materials to teach and assess learners effectively;
- ✓ Teachers must be able to match learning outcomes with instruction and assessment; and
- ✓ It can be affected by differences in abilities, interest or science background of learners.

Studies by Chang and Weng (2002) found that problem solving skills and process skills can be improved significantly using problem-based learning. Learners are capable of learning through experience, construct their own learning, thus making connections with the real world and seeing how science applies to them (Johnson, 2004). Learning outcome one in the Natural Science requires that learners must be taught 'scientific investigations' (Department of Education, 2002), which forms the basis of learning process skills. Suits (2004:249) found that Inquiry oriented instruction has a positive effect in acquiring investigative skills independently if they are taught explicitly.

1.2. RESEARCH OUTLINE

1.2.1 Research Problem

The National Curriculum Statement promotes teaching learners to become critical thinkers and problem solvers (Department of Education, 2003) who will do science the way scientists do (Roberts, 2001:113). Teaching science process skills through Inquiry has become central part of teaching Natural Science (Department of Education, 2003:9) and it is recognized as the foundation of science inquiry (Saat, 2003:23). It develops critical and creative thinking as learners investigate and experiment (Rambuda & Fraser, 2004:10). Science process skills are also regarded as the tools by which inquiry is conducted.

Interaction with educators led the present researcher to think that it is possible that science process skill of scientific investigation is not taught as stated in the Curriculum statement and educators might be experiencing problems in implementation and integrating scientific investigation. They might be still using the old traditional instruction methodology more often.

This study was guided by the question stated below:

- ⌘ How do Life Science and Natural Science educators teach the science process skill of scientific investigation?

In order to answer this research question, the following sub-problems were developed, namely:

1. Which inquiry instructional methodology is used by life and natural science educators in the teaching of scientific investigations?

2. Do the experienced educators use more open inquiry than less experienced educators for teaching scientific investigations?
3. Was the in-service training offered to educators had an effect on the choice of inquiry instruction in teaching scientific investigations?

1.2.2 Research Aim and Objectives

Teaching experimenting through inquiry requires time in terms of instructional planning, scheduling activities, developing collaborative relationships, implementing activities, supervising students' team work and assessing students' work. Educators must be professionally developed through in-service training in order to implement it effectively in class. This is vital because most educators had been in the system long before the curriculum based on OBE principles was implemented and thus they were generally not trained to teach this curriculum.

The training of educators in the region was conducted by curriculum implementers who were lecturers from the former colleges of education, that is, Hoxani College of Education and Mapulaneng College of Education. My experience during the workshop indicated that they had difficulties in clarifying some of the information. They also confessed that they were not properly trained hence the problems. Workshops were held over a period of three days, though the manual indicated that the work must be covered over a period of two to three weeks.

The aim of the present study was to explore quantitatively the teaching of scientific investigations by Life and Natural Sciences educators. The present researcher thought it might be possible that scientific investigations were not taught in science classes as outlined in the National Curriculum Statement.

Teachers' willingness to teach scientific investigations through inquiry was also explored. The study also investigated if educators feel they have enough time to teach through Inquiry, and what challenges and problems affect their teaching of scientific investigations.

1.2.3 Hypothesis

Hypothesis is defined as a process through which one tests generalizations from samples of populations (Martinez-Pons, 1999:88). It depicts and describes the research methodology that has to be used in an investigation (Bell, 1993:16) and is grounded on a theory (Borg, 1996:94). It must not be ambiguous but must be stated in a testable way. The study followed a non-experimental descriptive quantitative research.

The following null hypotheses were tested in the study:

I. There is no significant difference between the choice of Inquiry instruction and Life and Natural Sciences educators.

II. There is no significant difference between the choice of Inquiry instruction and experience in teaching Life and Natural Sciences

III. There is no significant difference between the choice of Inquiry instruction and period of in-service training educators received.

1.3 SIGNIFICANCE OF THE STUDY

The introduction of Outcomes Based Education (OBE) in our curriculum effected changes in science teaching and instructional methodologies used by educators. Here there has been a shift from content-based and teacher-dominated approach.

OBE teaching involves the use of more liberal learner-centered approach (Rambuda, 2003). Scientific literacy has become more important in our curriculum with the aims of producing scientifically literate citizen. Hence, the teaching of Natural Science should be seen as a means of improving the method of scientific thinking, providing students with more experience of explaining and interpreting their environment (Akkus, Kadayifci & Atasoy, 2003:209). Inquiry is regarded as basic to the teaching of science and science process skills are essential for educators teaching science.

The study will assist the Department of Education in providing information that will assist them in planning for further in-service training for educators. It reviews the status of teaching scientific investigations in Bushbuckridge Region schools. The study determines the extent of the needs educators require for the effective teaching of science process skill of investigation.

1.4 CONCEPTS AND DEFINITIONS

1.4.1 Science Process Skills

Science process skills are the sequence of events that are engaged by researchers while taking part in a scientific investigation (Arena, 1996:34). They are regarded as the building blocks from which tasks are based on (Department of Education, 2003:20). Science process skills are classified into basic process skills and integrated process skills. Rezba, Sprangue, Fiel, Funk, Okey and Jaus (1995) describe basic science process skills as ‘what learners do when they do science’. Basic science process skills provide intellectual background work in scientific inquiry (Beautmont-Waters & Soyibo, 2001:133). They include observation, prediction, classifying, inferring, measuring, recording and displaying data (Arena, 1996: 34-35; and Brotherton & Preece, 1996: 66).

Integrated science process skills are described as the terminal skills for solving problems or doing science experiments (Beautmont-Walters & Soyibo, 2001:133). They can be acquired if a learner has mastered the basic process skills (de Jager & Ferreira, 2003:188). Integrated science process skills are, namely, formulating a hypothesis, experimenting, controlling variables, interpreting data and defining variables operationally (Arena, 1996:34-35; and Brotherton & Preece, 1996:66).

1.4.2 Experimenting/Scientific Investigation

Experimenting is defined as a scientific investigation in which one attempts to test a hypothesis. Experimenting is an integrated process skill that involves questioning, identifying a problem, designing and planning an experiment (Saat, 2004:23; Rambuda & Fraser, 2004:11 and Chang & Weng, 2002:441). Some authors give a similar definition for both investigation and experimentation (Hackling & Fairbrother, 1996:26). Experimenting involves engaging in scientific investigations. In this study, scientific investigations and experimenting were used synonymously.

1.4.3 Inquiry Teaching

Inquiry is defined by Martin-Hansen (2002:35) as a student-centred approach that begins with student's question, followed by designing and conducting an investigation, and then answering the question.

Rambuda (2003:21) defines inquiry as a systematic method of teaching by giving learners inquiry tasks that develop learners' thinking skills. Students learn to articulate from their own testable hypothesis and research problems. Inquiry instruction is more learner-centred and not like the steps in a recipe or cookbook. The following three types of Inquiry as described by Martin-Hansen (2002:37) are dealt with in this study, namely, Open inquiry, Guided inquiry and Structured inquiry.

1.5 DEMARCATION OF THE STUDY

The study was undertaken in the field of Natural and Life Sciences in the Bushbuckridge region in Mpumalanga Province. Teachers in the region were trained to implement the new curriculum by the department. The study focused on teaching and assessment of scientific investigations in Natural and Life Sciences classes. Teachers' ability to use inquiry activities in teaching and assessing scientific investigations was also investigated. The participants in the study were educators teaching Natural and Life Sciences in secondary schools.

1.6 RESEARCH DESIGN AND METHODOLOGY

The study followed a non-experimental descriptive quantitative research. Lodico, Spaulding and Voegtle (2006:12) describe descriptive research as aiming "to describe behaviours and to gather people's perceptions, opinions, attitudes and beliefs about a current issue in education". The study explored the teaching and assessment of scientific investigation using a questionnaire. Cluster sampling was used for the study and the procedure for selecting the sample was applied in a manner that ensures that it is representative of Bushbuckridge educators teaching the subjects (see further explanation in 3.3.1). Questionnaires were delivered through the circuit office after permission was granted from the circuit managers.

Permission for conducting the research was requested from the Bushbuckridge Regional office and the sampled schools (see Appendix C). All participating schools were given letters that guaranteed confidentiality of information (see Appendix E). A questionnaire was piloted among Life and Natural Science educators who were randomly selected before a final draft.

1.7 DATA ANALYSIS AND INTERPRETATION

Descriptive analysis methods were used for data interpretation, which included frequency tables, percentages and graphs. These methods were used in determining, amongst others, the methodology used and factors limiting educators in teaching scientific investigations. Inferential statistical technique, viz., the one way ANOVA, was used for testing the hypothesis under study. Expert knowledge and a pilot study were conducted to increase reliability and validity of the questionnaire.

1.8 SUMMARY

We are living in the information age, whereby information is expanding at a remarkable rate and science education has become a priority for developing countries. Educators need to use teaching methodologies that promote independent thinking for our learners. The department has a responsibility of empowering educators with skills that will help take our country to a higher level. Inquiry instruction needs to be taught effectively in our classes and our learners need to become inquirers and problem solvers. Our society requires more scientifically literate people, and much so, the fast growing technological world needs critical thinkers.

The present study has been organised into the following five chapters:

Chapter one deals with the background of the study. It provides the orientation with a description of the aims, objectives, rationale, hypotheses, the research questions, research design, definition of concepts and the programme of the study.

Chapter two deals with teaching methodologies for teaching scientific investigations, inquiry instruction and problems associated with teaching scientific investigations.

Chapter three deals with how the empirical investigation was conducted. It covers the research problem; hypothesis; research design and method; the instrument and the validity and reliability of the questionnaire; and data collection.

Chapter four deals with data analysis and data interpretation.

Chapter five deals with the implication of the study, the findings from literature and the study; implications of the study; recommendations; and conclusion.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The modern society has witnessed drastic technological changes and the development of scientific knowledge. Factual knowledge is expanding rapidly and has become so overwhelming for our learners that it is not possible to teach all facts (Fogle, 1985). Memorising facts and information is not regarded as the most important skill in today's era (Zion et al., 2004:65). Today, an understanding of how to get and make sense of all the information is regarded as basic. Adapting to these changes is also dependent on how the teaching process takes place in the classroom.

Learners need to be taught how to seek for information and to ask the relevant questions for any given circumstance. People are expected to use different scientific skills in their lives and working environment, hence teaching of these skills has become a priority for science teaching, even if they are not working in the scientific community (Huppert, Lomask & Lazarowitz, 2002:807). Educationists and curriculum developers encourages science teaching to include the teaching of science process skills and teaching learners to be true inquirers (Saat, 2004:23).

The Natural Science National Curriculum Statement and Life Sciences National Curriculum Statement put more emphasis on inquiry and the teaching of science process skills (Department of Education, 2002 and 2003), thus aligning itself with societal demands. Learning outcome one of life sciences states that ‘the learner must be able to explore confidently and investigate phenomena using inquiry skills’ (Department of Education, 2003:12) and in Natural Science is simplified as ‘scientific investigations’ (Department of Education, 2002:8). Learners must be able to demonstrate that they are able to experiment and use different science process skills.

Many writers have tied science inquiry and science process skills together in science teaching. A scientific inquirer must have a sound scientific knowledge. Scientific inquiry can be improved by teaching science process skills and process skills can be improved by teaching through inquiry. According to Shymansky, Hedges and Woodworth (1990:127), a curriculum that emphasizes inquiry is more effective in enhancing student performance than the traditional textbook programme.

In an article by Fogle (1985) about science teaching, there was a remark stating that learners need to have a first-hand experience in experimental activities. Shymansky et al., (1990) remarked in their article that experimenting should not be used as a verification exercise rather learners should actively participate in a search for scientific knowledge. Learners must be allowed to learn science by doing. They must be able to plan, carry out investigations and communicate the findings of the investigations.

Prior to 1996 (i.e., during the apartheid period), the education system and policies promoted a traditional teaching approach for most historically black schools. The system focused much on mastering content knowledge and examination was used as a main form for assessing learner performance. There was little room for authentic assessment and what learners can actually do than know. Teaching was not fostering and promoting independent and critical thinkers (Rambuda & Fraser, 2004:10).

Since the introduction of Curriculum 2005 and National Curriculum Statement, the Department of Education has been training educators to implement the Outcomes Based Education in classes. The training was used as a tool to equip the educators to teach process skills and use inquiry instruction as a mode of teaching scientific investigations as they are core in the curriculum. This was important because it was impossible to expect teachers to teach what they do not understand (Lederman & Zeidler, 1987:721).

Enough time and effort was therefore needed to ensure that the educators develop a sound and critical understanding of the nature of science for effective teaching techniques associated with the new curriculum changes (Tairab, 2001:86).

2.2 SCIENCE PROCESS SKILLS

Science is driven by the desire to understand the natural world and technology is driven by the need to meet human needs and solve human problems. Scientists engage in process skills to gain knowledge of natural phenomena and explaining the cause and effect. The role of promoting scientific literacy by teaching science process skills is also advocated in the National Curriculum Statement (Department of Education, 2002:4).

Science process skills are described by Rambuda and Fraser (2004:10) as activities that scientists execute when they study or investigate a problem. Science teaching requires the need to teach the nature of science, and this should include the teaching of science process skills (Abd-El-Khalik & Lederman, 2000).

Process skills are classified as basic science process skills and integrated science process skills. The classification of process skills depends on the cognitive ability required for the skills. Process skills are important in science teaching and:

- are needed to analyse real life problems;
- help generate scientific knowledge (Rillero, 1998:3); and
- they have a positive influence on logical thinking.

(Padilla, Okey & Dillashaw, 1983:245)

2.2.1 Basic Science Process Skills

Rezba et al., (1995) described basic science process skills as what learners do when they do science. Basic science process skills apply to foundational cognitive functioning in the primary grades (Rambuda, 2004:11) and they provide the intellectual background in scientific inquiry (Beautmont-Walters & Soyibo, 2001:133). The ability to perform basic science process skills is attributed to the ability to perform Piagetian Concrete Operational reasoning (Germann & Aram, 1996). They are required by learners to advance their knowledge of science and for mastering advanced integrated process skills (Brotherton & Preece, 1999). The basic science process skills discussed below are observation, inferring, prediction, classifying, measuring, recording, communication and displaying data (Arena, 1996:34-35; Beautmont-Walters & Soyibo, 2001:133; and Brotherton & Preece, 1996:66). The basic science process skills are briefly described below.

2.2.1.1 Observation

Science begins with observations of objects and events; hence it is regarded as the most basic process in scientific investigations (Padilla & Pyle, 1996:23). Correct observations can lead to curiosity and asking of more questions. Observation is defined by (Padilla & Pyle, 1996:23; Colvill & Pattie, 2002a: 21; and Rezba et al., 1995:3) as the use of senses to gather data or information about a phenomenon. Rezba et al., (1995:4) list five senses people use for observations, namely:

- **Sense of hearing**: it is the use of ears to identify varying sounds from different objects, such as sounds of animals;
- **Sense of sight:** this involves the use of eyes to observe what happens in our surrounding and natural setting, and make judgement or interpretations;
- **Sense of touch**: the sense of touch is distributed throughout the body. Nerve endings in the skin and other parts of the body transmit sensations to the brain. Through this sense, learners can identify differences in pressure and temperature;
- **Sense of smell**: it is the use of a nose to identify different smells using smell receptors in the nose cavity; and
- **Sense of taste**: it involves the use of a tongue to identify different types of tastes using taste buds in the tongue.

Jegede and Okebukola (1991:37) describe scientific observation as an "act of recognising and noting a phenomenon". Observation demands paying a watchful and critical attention to a phenomenon investigated (Jegede & Okebukola, 1991:38). Observations should be relevant to the question, and the skills of observations have to be taught and learned (Hudson, 1993:121). When observing in the sciences, learners have to acquire the conceptual framework. It provides a base from which generalisations are drawn and certain predictions can be made. It is can be influenced by past experience and requires careful recording and description. Observation may lead to the use of the information to other process skills such as communicating their findings, classifying and predicting.

2.2.1.2 Classification

Classification is defined by Colvill and Pattie (2002b:27) as "grouping objects by common characteristics". Learners learn classification skill by observing similarities, differences and relationships in properties.

2.2.1.3 Measurement

Measurement is the use of standard guidelines (like metric system) to describe exact dimensions or using an estimate to determine the dimensions of an object or event. Students learn to use measuring instruments accurately and where to apply them.

2.2.1.4 Prediction

Colvill and Pattie (2002a:22) define prediction as the "expectation that an event will occur based on previous observations". When providing learners with challenges, they can use their pre-experience to predict an outcome of an investigation. Prediction skills are important in guiding learners to develop hypothesis.

2.2.1.5 Inference

It is the use of their past experiences to interpret or explain a set of observations (Rezba et al., 1995:117). To infer is also described by Padilla and Pyle (1996:23) as "the ability to conclude or make an educated guess based on evidence or past experiences". Learners are also able to use the inference skills to identify patterns and trends. It can also be used for developing a hypothesis and in interpreting data.

2.2.1.6 Communication

It is a process of using words, charts, body language, numbers, music, graphs, mind maps, models, data tables, oral presentation, charts and drawings to describe and/or report to other people (Rezba et al., 1995:19). During scientific investigations, information from observation and experimentation can made available to the scientific community (for learners it can start from fellow learners and teachers) for independent confirmation and testing through communication.

2.2.2 Integrated Science Process Skills

Integrated process skills are described as the terminal skills for solving problems or doing science experiments (Beautmont-Walters & Soyibo, 2001:133). Integrated process skills can be attained if a learner has mastered the basic process skills (de Jager & Ferreira, 2003:188) and learning them relies upon higher cognitive abilities (Arena, 1996:34). Integrated process skills are more complex than basic science process skills.

Integrated process skills are required to independently execute scientific experiments as learners inquire about how things are and why they are (Rezba et al., 1995). They are acquired when learners are engaged in inquiry activities wherein they seek answers to problems through experimenting. Science process skills are acquired when learners plan and carry scientific investigations. Integrated process skills are interpreting data, controlling of variables, formulating a hypothesis, defining variables operationally, controlling variables and experimenting (Arena, 1996:34-35; and Brotherton & Preece, 1996:66). A brief description of some integrated science process skills is given below:

2.2.2.1 Controlling variables

Learners identify variables that can affect an experimental outcome, keeping most constant while manipulating only the independent variable.

2.2.2.2 Defining variables operationally

They state how to measure a variable in an experiment. It involves creating a definition, which is in the context of learners’ knowledge or experiences, by describing what is done and observed.

2.2.2.3 Formulating a hypothesis

It involves the use of information to make a best educated guess about the expected outcome of an experiment. Learners suggest tentative answers to problems before they start with their investigative procedure.

2.2.2.4 Interpreting data

It requires that students collect observations and measurements (i.e., data) in an organized way and that they draw conclusions from the information obtained.

2.2.2.5 Experimenting

It requires involves designing and conducting a controlled scientific test. This consists of asking a research question; forming a hypothesis; identifying and controlling variables; using operational definitions; conducting the experiment; and interpreting the data. Experimenting is discussed in the next section (2.3).

2.3 SCIENTIFIC INVESTIGATIONS/EXPERIMENTING

Scientific investigations are a core component of most science curricula (Mbano, 2004:105) and the South African education system is not an exception. Experimenting is as an integrated science process skill (Saat, 2004:23; Rambuda & Fraser, 2004:11; and Chang & Weng, 2002:441). Scientific investigations are scientific problems or tasks that require learners to plan and carry out an investigation (Mbano, 2004:105). Tamir, Dorant and Chye (1992:266) describe experimenting as consisting of planning and designing experiments and involve the following:

- Formulating a question or defining a problem to be investigated;
- Formulating a hypothesis to be tested;
- Predicting experimental results;
- Designing a procedure to be followed; and
- Identifying and controlling variables.

Rambuda (2003:95) describes experimenting as an opportunity that provides the ability to apply all process skills. Learners design hands-on experiments to seek scientific knowledge. The laboratory where experiments take place should not be viewed as an organizational setting where demonstration and verification exercises take place (Tamir, et al., 1992).

Hackling and Fairbrother (1996:26) define "scientific investigations as a scientific problem which requires the student to plan a course of action, carry out an activity and collect the necessary data, organize and interpret the data, and reach a conclusion which is communicated in some form". Students' ability to perform science processes successfully during experimental inquiry depends on their previous experience, knowledge and skills (German & Aram, 1996:777). Greenwald (2000:28) states that learners learn science best by experiencing challenging problems and being given the opportunity to solve these problems. Teaching science requires learners to have first-hand experience in experimenting (Fogle, 1985). In this study, scientific investigations and experimenting were used synonymously.

2.4 INQUIRY INSTRUCTION

Martin-Hansen (2002:35) defines inquiry as the work scientists do when they study the natural world, proposing explanations that include evidence gathered from the world around them. Rambuda (2003:21) defines inquiry as a systematic method of teaching by giving learners inquiry tasks that develop learners thinking skills. Inquiry focuses on an active search of knowledge using scientific evidence to satisfy our curiosity as humans. It requires the use of critical and logical thinking and considerations of alternative explanations. Inquiry instruction is a student centred approach based on substantially increased student involvement in the learning process. Inquiry learning involves a process of exploration by learners that leads to questioning, making discoveries, and testing those discoveries while searching for understanding

In an article by Suits (2004:252) on inquiry instruction, the author concluded that there was a significant difference was found on learners' acquisitions of investigative skills when using inquiry instruction. Learners exposed to inquiry instruction were able to improve their ability to do scientific investigations. In the science classroom, learners become inquirers by posing questions that are of interest to them. They plan investigations with the view of finding answers to their problems. They collect evidence through experimentation and communicate their findings with peers and educators using correct scientific procedures. Questions asked by learners are dependent on their experiences in class, reference to available resources and observation in their environment.

Roth and Roychoudhury (1996) outlined the following four levels of inquiry used in a science class:

0 – They described this level as the first and referred to as observation laboratory instruction. Learners are engaged largely on observation activities. They are not directly engaged in the manipulation and use of materials or equipments. They passively observe the educator or a selected few learners work with the materials.

1 – At this level, learners are provided with prepared laboratory manuals with poses problems to be answered. The provided documents describe how the solutions can be reached. This level is higher than level 0, as learners are engaged in scientific investigations.

2 – Problems are provided with laboratory manuals, however, methods and solutions are left open for the learners to discover them.

3 – This is described as the highest level of the four. Problems, answers and methods are left open for learners to work through. Learners are confronted with raw phenomena. Teaching is centred around the learners who take centre stage, guided by the educator during the activities.

Teaching using a higher level is at times limited by the resources learners have. Provision by the educator must be made to expose learners to higher levels. Educators can request learners to bring used materials they have at home.

Inquiry is characterized by an emphasis on problem solving, collaborative group work and critical thinking (Zion et al., 2004). Bybee (2004:9) describes inquiry features that can be essential in teaching scientific investigations and such are outlined below:

- Learner engages in scientifically oriented question;
- Learners gives priority to evidence in responding to questions;
- Learner uses evidence to develop an explanation;
- Learner connects the explanation to scientific knowledge; and
- Learner communicates and justifies the explanation.

Inquiry instruction is a threat to traditional dominant role of the teacher in a science class. The traditional teaching style cycles around the teacher who decides what is to be investigated and how. In inquiry classrooms, learners take centre stage and the teacher becomes only the guider and facilitator (Rambuda, 2003; Roth & Roychoudhury, 1996; and Germann, 1989). Domain (1999), in Anders et al., (2003: 352), lists four laboratory instruction style. These are, namely, expository, open inquiry, discovery and problem solving. These instructional methods are differentiated by the outcome of instruction (pre determined or undetermined), teaching approach (deductive or inductive) and procedure (given or student generated).

Three types of inquiry are discussed in this study. They are, namely, open inquiry, guided inquiry and directed (structured) inquiry.

2.4.1 Open Inquiry

Hansen-Martine (2002:35) defined open inquiry as a student-centered approach that begins with a student's questions followed by the student designing and conducting an investigation to answer their question. They then communicate the results. Open inquiry mirrors what scientists actually do in the field of work. Learners continuously ask questions and are given an opportunity to answer these questions through experimenting (Roth & Roychoudhury, 1996:141). The involvement of the teacher is minimal.

The outcome is not predetermined for the learners, and they are expected to apply inductive reasoning. In an open inquiry environment learners must be exposed to a variety of experiences to activate their ability to ask relevant scientific questions (Hackling & Fairbrother, 1996:28). They need to be given resources which they can read. Open inquiry requires higher order thinking and allows students work directly with materials.

2.4.2 Guided Inquiry

Guided inquiry slightly differs with open Inquiry. Educator and students work together in deciding on the direction of the investigation and how to proceed with the investigation (Hansen-Martine, 2002:35). The teacher becomes less involved as compared to Open inquiry instruction.

The educator, at times, provides different questions and problems for investigation and answers are left open for the learners to investigate (Roth & Roychoudhury, 1996). The questions can be discussed in groups with the guidance of the educator. Learners are not totally independent in their investigations.

Guided inquiry can often lead to open inquiry investigations. Learners who are not yet familiar with Open inquiry can be introduced to inquiry through guided inquiry until they become familiar with the processes and the skills involved in conducting independent investigation (Martin-Hansen, 2002:35). Learners who encounter difficulties in conducting open investigations can be given an opportunity to learn and experience inquiry directly with the assistance of the teacher.

When learners become familiar with inquiry investigations, the contributions of the teacher becomes minimal and learners take centre stage.

2.4.3 Structured inquiry/Directed Inquiry/Cookbook inquiry

Directed inquiry is described by Martin-Hansen (2002:37) as a mode of instruction directed by the teacher. It is more teacher-centered as compared to the other two types of inquiry. Directed inquiry is also referred to as Cookbook inquiry by other authors (Martin-Hansen, 2002:37; and Suits, 2004). There is little active involvement of learners In Directed inquiry, the investigations, methods to be used, expected results and explanations of the scientific phenomena observed are made available to learners by the teacher or provided by ready made material.

Learners may be involved in activities that are not necessarily connected to each other in Directed inquiry and can be short hands-on investigations that may not promoting scientific inquiry (Moscovici & Nelson, 1998:14). During investigations, learners focus on the hypothesis clearly defined by the teacher or supplied. Learners tend to disregard results that do not meet the expectations laid down prior to experimentation. Learners engaged in cookbook investigations are less engaged in creative higher thinking skills (Martin-Hansen, 2002:37) and are more depended on their teachers. Directed inquiry de-emphasises investigative skill development (Suits, 2004:248). In directed inquiry activities learners can also be provided with options to decide how they can improve an experiment or providing alternative ways to solve a problem.

Directed inquiry can be used at initial stages of teaching learners inquiry activities. It should be used with the aim of introducing learners to do Open inquiry investigations. It should not be used as the only methodology to teach investigations in secondary schools.

Educators should use structured inquiry to engage students in activities that provide them with background knowledge of scientific concepts. The knowledge should stimulate them by providing them with stimulating questions that can lead to further investigations.

Learners should be taught skills that they can use to explore beyond the concepts that were discussed. Educators can move from providing them with expected answers and leave them to explore on their own while they are being assisted. The table below shows classroom inquiry and their variations.

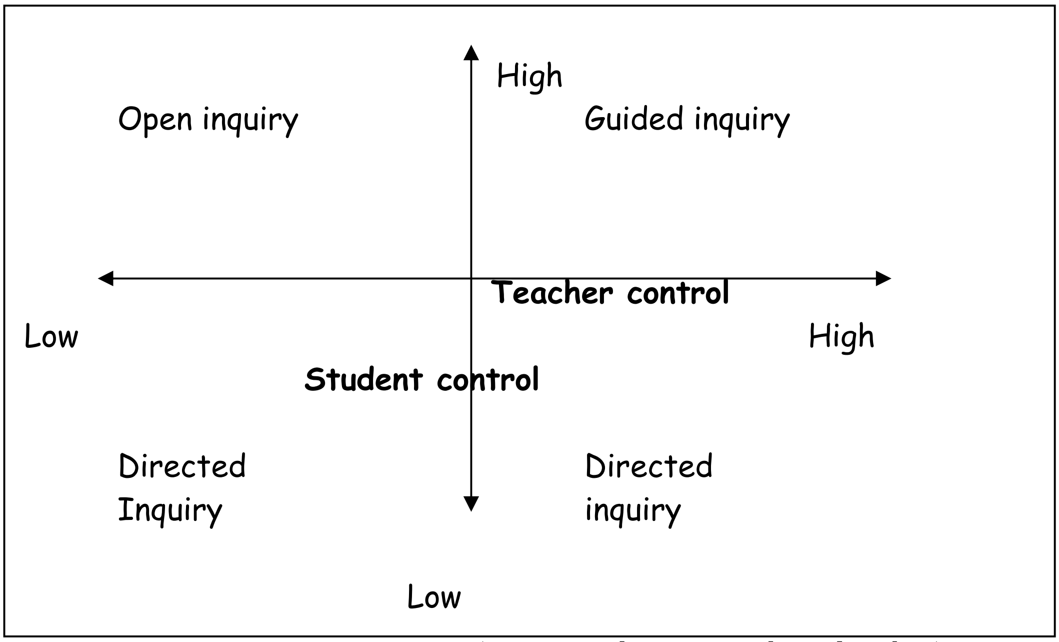
Table 2.1 Summary of classroom inquiry and their variations

Open inquiry	**Guided inquiry**	**Directed Inquiry**
Learners poses questions to be investigated after exposed to a problem	Learners clarify or sharpen questions provided by a teacher or other materials.	Learners engage in questions provided in textbooks or by a teacher or other materials.
Learners plan and conduct investigations with minimal interference from teachers	Learners work with teachers on deciding how the investigations will be carried out	Experimental procedures are provided

Less Amount of direction from the teacher More

(Adapted from Martin-Hansen, *2002:36)*

Below (Figure 2.1) is a sketch that illustrates the role of an educator and a learner in inquiry activities.



(Source: unknown article and author)

Figure 2.1: Control of the science class during inquiry

The sketch above (Figure 2.1) indicates that in guided inquiry both learners and the educator they have a high control of the learning situation. In Open inquiry, the teacher has minimal control of the learning situation by allowing learners to contribute more and guide them in the learning environment.

2.5 OUTCOMES-BASED EDUCATION AND SCIENTIFIC INVESTIGATIONS

The curriculum emphasizes higher cognitive skills and the integration of processes into the core of the instruction. Learning outcome one in the Revised National Curriculum Statement requires learners to conduct investigations (Department of Education, 2002:8). Outcome–Based Education, as outlined by Rambuda and Ferreira (2003:124) and Department of Education (2002), is important because it reduces rote memorization by focusing on the outcomes of learning; increases learners' ability to appreciate; deals with real-life experiences; eliminates permanent failure to learners; and gives all learners an opportunity to demonstrate what they have learned and can do. The Revised National Curriculum Statement supports the scientific investigations and the process skill of experimenting in particular.

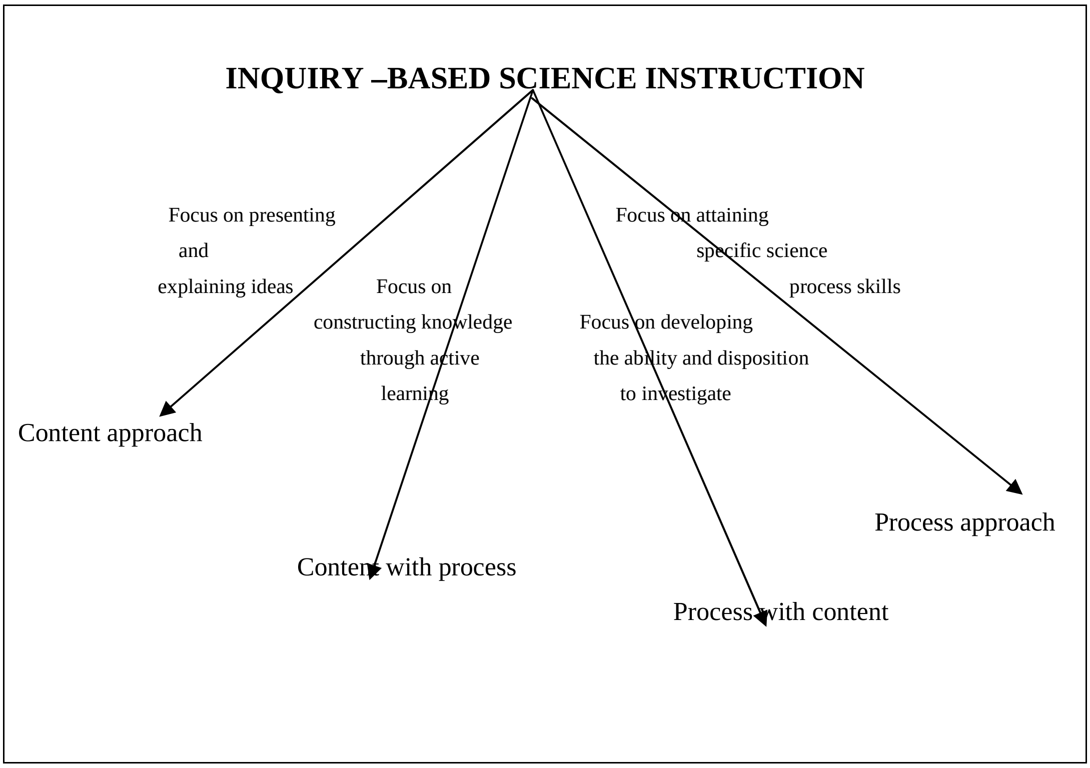
Most of the articles had been written in other countries where inquiry had been implemented. By the early twentieth century, Inquiry Instruction was advocated in the United States (Deboer, 2004).

2.6 TEACHING EXPERIMENTATION THROUGH INQUIRY

Inquiry is a threat to traditional dominant role of the teacher in a science class. In inquiry, learners take centre stage and the teacher becomes the facilitator and guide (German, 1989; and Roth & Roychoudhury, 1996:141). Engaging learners in practical activities has several advantages as identified by Hudson (1992:117), which are, namely:

- To motivate learners by stimulating interest and enjoyment;
- To enhance the learning of scientific knowledge;
- To teach laboratory skills;
- To develop expertise in and provide experience of, conducting scientific investigations; and
- To develop scientific attitudes.

Chiappette and Adams (2004:47) identified four different aspects of inquiry-based science instruction and it has been summarised in Figure 2.2 below.



Adapted from Chiappette and Adams (2004: 47)

Figure 2.2: Different aspects of inquiry-based science instruction

As illustrated in Figure 2.2 above, there are four inquiry instruction methods identified by Chiappette and Adams (2004:47). These methods outlined the focus area of each teaching methodology, thus each method aims for a particular outcome.

Science teaching does not oppose the acquisition of factual knowledge (Rutherford, 1964:80). Learning outcome two (i.e., of Natural Science and Life Science) required the planning of lesson that such that learners are able to acquire science knowledge. Science content comprises laws, concepts, principles and theories and these form the foundations upon which science is build and progress (Chiappette & Adams, 2004:48). Teachers can use content process in class by engaging learners in activities of linking content and investigation activities with the view of allowing learners to gain science knowledge.

Inquiry should be encouraging learners to be inquisitive, curious, ask relevant questions in a given situation and try to search for solutions by themselves (Rutherford, 1964:80).

A big questioning in the mind of many is whether the planning of lessons focuses on language acquisition or goes beyond teaching learners to be inquirers and problem solvers.

Learners can be encouraged to solve problems which they do not have straight forward answers. Questions should be open-ended giving learners the option to think creatively. The educator then encourages learners to bring their own questions and search for possible solutions. Educators guide them than taking a authoritative leading role.

Greasley et al., in Rambunda (2002:61-62), outlined the characteristics of inquiry based learning as follows:

- Knowledge and understanding are developed by a structured-questioning approach;
- An emphasis on problem solving;
- Collaborative group work;
- Decision making;
- The identification and development of views and attitudes;
- The exploration of a range of viewpoints; and
- Open-ended outcomes to inquiry.

Inquiry teaching is seen as occurring as a continuum rather than a once-off activity. The design of learning activities in teaching investigative process skill involves the inclusion of open- ended activities requiring learners to actively search for answers. Teachers guide learners in activities as learners working towards their finding solutions to problems given to them.

Shipman (2004:368) identified different inquiry strategies that can be used to teach process skills. They include problem-based learning and jigsaw (cooperative learning), and these two are dealt with in this study.

2.6.1 Problem-Based Instruction

Problem based instruction is another vehicle used for inquiry based learning (Greenwald, 2000:28). Learners use a problem as a context for an in-depth investigation of what they want to know. Questions are not only used to provoke feedback only. They can be used to reflect what the learner knows and can do. Open-ended questions are used more often in inquiry activities as they do not limit learners in answering questions. Ways in which problem solving can be used in teaching scientific investigation (experimenting) is discussed below.

2.6.1.1 Ill-defined problems are presented to learners

Ill-defined problems can be presented in a manner that it is unclear and raises further questions about what is known, what needs to be known and how the learners can search for solutions (Greenwald, 2000:28). The questions challenge students' thinking and they continuously search for meaning. Questions can be asked by students and an opportunity and environment be provided to them to answer these questions.

2.6.1.2 Provide learners with a phenomena to ask questions

Teachers can provide learners with phenomena to ask questions. They can be encouraged to focus their attention on a particular aspect of what they are asked to observe and be encouraged to suggest possible follow-up investigations. To be successful in problem solving, learners must have background knowledge of content and context (Chang & Weng, 2002:441).

2.6.1.3 Suggest possible questions for investigations

Suggest possible questions for investigations (Edwards, 1997:20). The teacher acts as a guider from asking questions, investigating a problem and analyzing the results. The teacher's role is not to provide solutions, but rather can probe where learners are too vague or drifting away from the theme being studied.

2.6.2 Cooperative Learning

Watson (1991:141) defines cooperative learning as a "classroom learning environment in which students work together in small, mixed ability groups in terms of gender, ethnicity, race, academic ability and socio-economic background". Students are organized into groups and each group member is given a responsibility. Learners share knowledge and skills during scientific investigations. They become learning resources for each other. They then plan and design the experiments together as team with each member having a shared responsibility. Learners pose different questions, work together to refine the question and reach a consensus on what to investigate as a group.

Watson (1991) indicated that cooperative instruction increases enthusiasm for science and generates interest in understanding the views of other learners. In a survey by Johnson (2001), he found that there are 101 reasons for using cooperative learning in Biology, thus affirming the importance of cooperative learning. As Zion et al., (2004:59-60) indicated, it allows for the formation of a supportive climate for learning and division of work, and also promotes cognitive skills.

However, Cooperative instruction is not problem free (Lord, 2001:30). It is too time consuming if learners are not used to it, and too informal to bring about a high level of complicated material that older students need to know (Lord, 2001:30). It needs strong supervision of learners. Assessment of learners can be conducted individually or as groups based on the tool that is used. The contribution of each learner can be observed and assessed, and also their collective contribution can be considered.

2.7 ASSESSMENT OF THE PROCESS SKILL OF EXPERIMENTING

Assessment is defined as a process of gathering information about the performance of learners (Department of Education, 2002:77). Van der Horst and McDonald (1997:170) define assessment as a data gathering strategy for measuring knowledge, behaviour and performance. As outlined in the National Curriculum Statement, assessment is measured against the assessment standards of the learning outcome

Assessment should be used to help learners reflect on what they are doing well and what they need to do differently to improve their investigations (Hackling & Fairbrother, 1996:32). Assessing of experimental work can be used in relation to some content (Harlen, 1999:131). Assessment of experimenting should not only focus on examinations. Observation based and task based assessments should be used to assess science investigations (Department of Education, 2003:44-45).

Learners can be assessed on how they link theory and practical work. Assessment should not be a once off activity. Students need enough opportunities to practice the process skills within a variety of investigative activities (Germann & Aram, 1996:775). They should be provided with feedback on a continuous basis. Below, three forms of assessment are briefly described and are baseline, formative and summative assessment.

2.7.1 Baseline assessment

This form of assessment will provide the educator with the background knowledge of what the learners know in terms of conducting investigations. It will help the educator know the level of inquiry that should be used.

2.7.2 Formative assessment.

It is used to gain an understanding of what the learners know in order to make the necessary changes to teaching and learning (Van der Horst & McDonald, 1997:171). Formative assessment is ongoing and helps to monitor and improve progress of learning (Department of Education, 2003:42). Teachers can use Formative assessment to gather evidence of the sub-skills of experimenting acquired using a holistic or analytic rubric or other instruments. Teachers can assess their ability to state a hypothesis given a particular context or content or assessing their ability to communicate their findings. Formative assessment can be used to assess their ability to conduct a whole scale investigation, from stating a problem to reporting or a particular skill can be assessed at a time.

2.7.3 Summative assessment

Usually, this takes place after a task has been given or learning has taken place (Department of Education, 2003). Teachers can use formal practical investigations to assess individual learners or a group of learners to assess their overall knowledge of investigations. Teachers can asses their ability to experiment under different context and using a specified content.

The teacher can assess the process skill by observing the learners as they conduct an investigation, setting tasks that will require the learners to experiment, and asking learners to communicate their thinking through different modes, such as concept mapping, writing reports, role play, actions and drawings (Harlen, 1999:133).

Table 2.2. A rubric that can be used in scientific investigations

Criteria or Score	Outstanding achievement	Satisfactory achievement	Adequate achievement	Partial achievement	inadequate achievement
Question & / or Hypothesis	*Question or hypothesis has been thoroughly developed. Hypothesis is correctly stated with variables identified*	*Question or hypothesis has been sufficiently developed with reasonable relevancy*	*Question or hypothesis is partially developed with some relevancy*	*Question or hypothesis has major flaws and limited or no relevancy*	*No attempt has been made*
Score					

Investigation Design	*Investigation is a well-constructed test of the stated question or hypothesis. All of the developmentally appropriate components (materials, controls, procedure, safety) are arranged so that the investigation can be replicated exactly as described*	*Investigation is a reasonably constructed test. All of the components are reasonably arranged so that the investigation can be replicated.*	*Investigation is a partially constructed test. Some of the components are missing, making it difficult to replicate.*	*Test is not relevant to the question or hypothesis. Information is not sufficient to replicate investigation.*	*No attempt has been made*
Score					
Methods of Data Collection	*Significant data has been collected in the most efficient and appropriate ways. Data is accurately recorded and displayed using the most relevant and organized methods*	*A reasonable amount of data has been collected in a sufficient manner. Data is recorded and displayed using organized methods.*	*A minimum amount of data has been collected. Data is recorded and displayed but may lack some organization.*	*Insufficient data has been collected. Data has not been recorded or displayed in an organized way.*	*No attempt has been made to collect data.*
Score					

Data Analysis	*A precise statement of the investigation results relates directly to the question or hypothesis. Clear assumptions have been made from an accurate evaluation of the conclusion. Recommendations are clearly consistent with the findings of the investigation and provide an excellent defence.*	*A reasonable statement of the results shows a good relationship to the question or hypothesis. Reasonable assumptions have been made from the conclusion. Recommendations are reasonably consistent with the findings of the investigation and provide a good defence.*	*A statement of the results provides some relationship to the question or hypothesis. Assumptions are minimally supported by the conclusion. Recommendations are inconsistent with the findings and provide a questionable defence.*	*A statement of the results shows no relationship to the question or hypothesis. Assumptions are not supported by the conclusion. Recommendations show no relationship to the findings and provide a poor defence.*	*No attempt has been made.*
Score					

(Adapted from http://web.stclair.k12.il.us/splashd. accessed 3 August 2006)

2.8 THE ROLE OF THE TEACHER IN TEACHING EXPERIMENTATION

Inquiry instruction does not mean that educators do not totally present information to students, but rather that he/she is not solely responsible for imparting all of the information. The educator documents the students' progress with ongoing (formative) and summative assessments. The teacher must have an adequate understanding of the nature of science and how to use inquiry instruction for him/her to effectively teach and assess learners in the science. The teacher must create a rich variety of assessments for students to show what they know, and also to do the following:

* Make resources available to learners and guide them as they learn to be inquirers (Hackling & Fairbrother, 1996:26; and Zion et al., 2004:59);
* Plan how to handle inquiry activities in an overcrowded curriculum (Palmer, 1997);
* Use effective questioning strategies and encourage inquiry activities in the classroom (Johnson, 2004:48);
* Adapt science content to meet the interests, knowledge, and abilities of learners;
* Encourage participants to be responsible for their own learning (Johnson, 2004:48);
* Recognize diversity among participants, encourage participation by all learners and help learners take responsibility of their own learning (Hand & Vance, 1995);
* Must make time available to plan and teach inquiry activities; and
* Consider gender, culture, racial differences and knowledge background of learners when planning (Roth & Roychoudhury, 1993:127).

2.9 THE SIGNIFICANCE OF TEACHING AND LEARNING EXPERIMENTATION THROUGH INQUIRY

Science is founded on inquiry (Windschitl, 2000:82) and learners must learn to become inquirers. The way science is practised should be reflected in school science education by using the following inquiry instruction (Germann & Aram, 1996):

* Learners engaged in open laboratory inquiry activities tend to develop a positive attitude towards science and enjoy science activities (Tamir, et al., 1992:264);
* Inquiry oriented curriculum increases student achievement (Tamir, Stay and Ratier 1998:31). In a study by Shymansky, Hedges and Woodworth (1990: 138), it is outlined that inquiry based science curricula has a general positive

impact on student performance and academic achievement. It has a positive impact on process skill development and attitude towards science (Kass & Cobern, 1993; and Lee, 1993:626);

* Students learn to be problem solvers by posing questions and experimenting (Johnson, 2004:48-49). They learn to make sense of information when interpreting data collected;
* It reduces dependence upon the teacher. In cooperative group work they develop their expressive skills and build their vocabulary (Amaral, Garrison & Klentschy 2002:237). They are able to interact with peers more freely and help each other through their work (Lord, 2001:30 and Moscovici & Carty, 1999:41). They develop mutual responsibility (Hertz-Lazarowitz, Baird & Lazarowitz, 1994:70);
* It improves students' abilities to apply scientific concepts and principles to different environment (Zion, Shapira, Slezak, Link, Bashan, Brumer, Orian, Nussinovitch, Agrest & Mendolovici, 2004:65). They learn science content when experimenting (Roth & Roychoudhury, 1996). Learners need to apply scientific content knowledge at some stage of their investigations;
* Students learn and understand the nature of scientific inquiry (Germann & Aram, 1996:773; and Moscovici & Carty, 1999:41);
* Help learners develop scientific skills of thinking (Roth & Roychoudhury, 1996). Help learners develop skills necessary to become independent inquires about the natural world. They develop higher order thinking skills (Mbano, 2004:105). Activities designed at developing for scientific investigation encourages learners to think about their own thing and are able to reflect and share their learning experience;
* Inquiry invokes the intellectual skills of deduction, problem solving, critical thinking and creative thing to learners (Windschitl, 2000:82). It increases thinking ability and school achievement of learners (Mbano, 2004:105); and

* Experimenting offers context and content for teaching science process skills (Rillero, 1998:3). It emphasizes integration of content and process.

Performance of learners on scientific investigations depends on their understanding of scientific facts, laws and principles and how to put science into practice (Mbano, 2004:105). Learners must have knowledge of handling conducting practical activities, handle equipments and be able to design, measure, handle data and be able to correctly evaluate the evidence.

2.10 PROBLEMS ASSOCIATED WITH THE TEACHING SCIENTIFIC INVESTIGATIONS

The teaching of science process skills and scientific investigations in particular in sciences is basic. These skills need to be taught and developed in our learners. In a quantitative study by de Jager and Ferreira (2003) on Biology (Life Science), they acknowledge that in South Africa there are several factors that prevent the development of process skills. Problems associated with the teaching of science process skills develops from different stake holders in the education system. Some of the factors that are associated with the teaching of scientific investigations are briefly discussed below.

2.10.1 Teacher preparation

Teaching experimentation requires time to plan and integrate inquiry into the curriculum. Teachers lack sufficient training to use inquiry in their classroom. Teachers also lack the philosophical background of Outcomes-Based Education the backbone of active participation of learners (Muwanga-Zake, 2005). Some educators do not have knowledge on how to use available apparatus in their school; hence they avoid scientific investigations (Muwanga-Zake, 2005).

2.10.2 Lack of resources

Inquiry instructions require the availability of certain infrastructure for conducting scientific investigations and materials to be used during the investigations (Jager & Ferreira, 2003:196).

Shortage of materials can hamper the implementation of inquiry process in the science classroom. Learners are forced to memorise experiments than experimenting themselves. Lack of resources may result in a situation where teachers resort to traditional teaching methodology (Meier, 2003:232).

2.10.3 Pressure to cover content and focusing on examinations

According to Abd-El-Khalik and Lederman (2000:670), in South Africa, there is a poor output of science learners and pressure is on educators to improve results. This led to educators using survival strategies to ensure that results improve and, as a result, the method compromises the use of inquiry teaching.

2.10.4 Teaching methodology.

Teachers are relying on traditional methods in teaching experimentation. Educators complain that students cannot read inquiry materials, and both students and teachers feel uncomfortable about inquiry (Germann, 1989:238).

Teaching scientific investigations requires comprehensive preparation from learners and the teacher. Learners need to be taken through a series of experiences that may require them become familiar with higher order thinking and open-ended inquiry.

2.11 SUMMARY

Introduction of scientific investigation as a learning outcome in Natural Science has shifted focus in our curriculum. Many researches have been made on using inquiry in developed countries and if we are able to learn from them we can improve the teaching of science process skills. The journals are not readily available to high school teachers and this makes it difficult for educators in the region

It is the main responsibility of educators to ensure that learners are taught scientific investigations. The country needs highly skilled people who are scientifically literate even if they would not be scientists. A scientifically literate learner does not mean that they should memorise all the science facts. Learners must be taught how to ask inquiry questions and an opportunity be provided to them to experiment in the quest to find solutions to their problems.

Though it is difficult to implement inquiry activities, they can be acquired if learners are taught. Teachers should strive to move from the traditional cookbook investigations to open inquiry. Educators should note that there is no single method of inquiry. It differs on the outcomes and the purpose the teacher has and the maximum use of available resources. Using too much open inquiry has a possibility that students will be lost. Using inquiry to teach experimenting has some benefits to learners. Educators must use different form of assessment, this will ensure that the learners are supported and developed under a given conditions. Teaching this process skill requires time to train educators to use inquiry instruction.

This chapter focused on literature review related to the topic presented in Chapter one. Science process skills are classified into basic and integrated process skills. Process skills are activities learners engage in when experimenting. Basic process skills are less complex than integrated process skills. The basic process skills discussed briefly in this study are, namely, classification, measuring, prediction, inference, and communication. Integrated process skills described in this study are, namely, controlling variables, defining variables operationally, formulating a hypothesis, interpreting data and experimenting.

Inquiry instruction is differentiated by Roth and Roychoudhury (1993) into four levels. The higher the levels the more cognitive demands are required. Other authors like

Hackling and Fairbrother (1996) and Hansen-Martine (2002) group it into three types, namely: open, directed and guided inquiry. A relationship in instruction in teaching experimenting and inquiry had been found.

Scientific investigations can be taught through problems based instruction and cooperative instruction. Different forms of investigations can be used to assess learners, which includes formative, summative and baseline assessment. Teaching scientific investigations is problematic to institutions where educators have limited knowledge and/or resources.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

In Chapter one and Chapter two, the orientation of this study and an extensive literature review on teaching of scientific investigations were presented respectively. This chapter describes the research design and methodology components used in the study.

3.2 RESEARCH QUESTION

The research question for this study as stated in 1.2 is restated below.

- How do Life Sciences and Natural Science educators teach the science process skill of scientific investigation?

The following sub-problems were studied:

1. Which inquiry instructional methodology is used by life and natural science educators in the teaching of scientific investigations?
2. Do the experienced educators use Open inquiry more than less experienced educators for teaching scientific investigations?
3. Was the in-service training offered to educators had an effect on the choice of inquiry instruction in teaching scientific investigations?

3.3 RESEARCH DESIGN

Research Design is described as a strategy, a plan and a structure of conducting a research study, and it provides the overall framework for collecting data (Leedy & Ormrod, 2001:97). It refers to a plan for selecting subjects, research sites and data collection procedures to answer the research questions (McMillan & Schumacher, 2001:166).

As described in McMillan and Schumacher (2001:166) and Cohen, Manion and Morrison (2000:75), research design details comprise the following:

- The selection of subjects;
- Research site(s);
- Conditions for conducting research;
- Data collection procedures;
- Data analysis methods; and
- How the results will be presented.

The goal of a Research Design is to have research that will provide results that are judged to be trustworthy and reasonable (McMillan & Schumacher, 2007:117). It focuses on methods of collecting evidence (data) by addressing the question(s) being studied and/or research hypothesis (Vogt, 2007:7). A good Research Design appropriate for a particular study depends on the research problem or question under investigation (Vogt, 2007:49; and McMillan & Schumacher, 2001:166).

Two types of Research Designs used in most educational research are, namely, quantitative and qualitative methods. Quantitative research explains phenomena by collecting numerical (quantitative) data and analysing it using mathematically bases methods; in particular statistics (Johnson & Christensen, 2004:31-32; and Muijs 2004:1). Quantitative research generally focuses on hypothesis testing and one or few factors are studied at a time (Johnson & Christensen, 2004:30-33; and Best & Kahn, 1993:186). It seeks to reduce data to numbers that represent a single criterion.

Qualitative research explores traits of individuals and settings that cannot be easily described numerically (De Vos, 1998:15) and is more concerned with understanding the social phenomenon from participants' perspective than explaining a phenomenon (McMillan & Schumacher, 2001:17; and De Vos, 1998:242). For this study, a quantitative survey research was regarded as appropriate.

Quantitative research is classified as either experimental or non-experimental design (Muijs, 2004:13). Experimental research is “a test under controlled conditions that is made to demonstrate a known truth or examine the validity of a hypothesis” (Muijs, 2004:13). Experimental research method is designed to study casual relationships between variables (Johnson & Christensen, 2004:263). It takes place under controlled conditions and there is a greater control of confounding extraneous variables. For this study, a non-experimental research method was used.

In Johnson and Christensen (2004:328), non-experimental research is defined as:

> [a] systematic empirical inquiry in which the scientist does not have direct control of independent variables because their manifestations have already occurred or because they are inherently not manipulatable. Inferences about relations among variables are made, without direct intervention.

In non-experimental design, there is no control of conditions and extraneous influences (Johnson & Christensen (2004:328). The variables are used as they appear in practice. Non-experimental research methods include survey research, historical research, observation and analysis of existing data sets (McMillan & Schumacher, 2001:283).

Survey research is highly flexible (Muijs 2004:44) and makes it possible to study a wide range of topics. The advantage of survey research is that it is easy to generalize the findings to real-world settings. Large amounts of data can be gathered at reasonable low costs. Respondents’ anonymity can be easily guaranteed, especially with a questionnaire (Muijs, 2004:44-45). In a survey research, the researcher collect data from participants and summarise their responses with percentages, frequencies or other statistical methods and then make inferences from the collected data to a particular population. A cross-sectional research was used for the study.

In a cross-sectional research, data are collected from the research participants at a single point in time or during a single relatively brief time period (Johnson & Christensen, 2004:343.). Data can be collected on many different kinds of people in relatively short period of time.

Three forms of non experimental quantitative research are often used and are descriptive research, predictive research and exploratory research (Johnson & Christensen, 2004:347). The study followed a descriptive form. Descriptive research provides an accurate description or picture of the characteristics or status of a situation (Johnson & Christensen, 2004:347). It focuses on describing the variables that exist in a given situation. Descriptive research reports things as they are or were (McMillan & Schumacher, 2001:283).

3.3.1 Population

Bless and Higson–Smith (1995:85) define a population as the entire set of people, events or objects which is the object of research and about which the researcher wants to determine some characteristics. In a study, selected individuals, called a sample (see section 3.3.2), used for a study are drawn from the entire population. The Bushbuckridge Region was formerly divided into three area offices, namely, Mkhuhlu, Acornhoek and Bushbuckridge. During the time of the study, there were 115 schools that offered Natural Life sciences. The population consisted of high school educators teaching both science subjects in Grade 08 to Grade 10 in Bushbuckridge.

3.3.2 Sampling

Sampling is the process of selecting participants/subjects from a population of interest and data are collected from the small group (sample) in order to learn about the large group (population) (Vogt, 2007:77). Sampling is important in research as it is sometimes difficult to study the entire population. A Sample is described by McMillan and Schumacher (2001:169) as a “group of elements or cases, whether individuals, objects or events, that conform to specific criteria and to which we intend to generalize the results of the population”.

The research was conducted in the Bushbuckridge Region in Mpumalanga Province. This region is a former Limpopo Province district, hence all the training of educators was conducted by officials from Limpopo. The target population is Life and Natural Science educators teaching Grades eight to ten. Natural Science and Life Science are taught by educators who majored in Biology and/or Physical Science.

There are different forms of probability sampling method used by educational researchers and the most common ones are Simple random sampling, Stratified random sampling, Systematic sampling and Cluster sampling (McMillan & Schumacher, 2001:170).

To study the teaching of scientific investigations, a sample representative of the population was targeted for the study. Probability sampling method was used for the study. In Probability sampling, the subjects are drawn from the population in such a way that the probability of selecting each member of the population is known (McMillan & Schumacher, 2001:170). Random sampling method eliminates sampling bias and minimises sampling error as there is no systematic under- and overrepresentation of some members of the population in a sample (Vogt, 2004:78). For the purpose of this study, a Cluster random sampling method was used.

In Cluster sampling, the researcher identifies, naturally occurring group units then randomly selects units of the study (McMillan & Schumacher, 2001:173; and Johnson & Christensen, 2004:211). The population is divided into smaller groups called clusters. Each cluster should have all the characteristics of the whole population.

Cluster sampling is often used when the elements of the population are geographically spread out and when it is difficult to select a simple random sample from the target population (Vogt, 2007:80; and Cohen et al., 2000:101). A cluster must be representative of the population and a larger sample size is required as compared to Simple random sampling, Systematic sampling and Stratified sampling (Johnson & Christensen, 2004:211). A good sampling practice that ensures that all characteristics of a population are represented reduces threats to external validity (Vogt, 2007:82).

The Bushbuckridge Region was formerly divided into three area offices. This very same demarcation was used to form clusters for the sample. The clusters were considered to be homogenous in respect to training educators received except where educators received additional training and distribution of resources in these schools. Cluster sampling was taken after consideration of cost, convenience and time involved in the distribution and collection of the instrument.

3.3.3. The Research Instrument

For this study, a questionnaire was considered to be appropriate as a data collecting instrument. A questionnaire is the most widely used technique for obtaining information from subjects (McMillan & Schumacher, 2001:256). Johnson and Christensen (2004:164) define a questionnaire as "a self-report data collection instrument that each research participant fills out as part of a research study". A questionnaire is used to measure different kinds of characteristics. It can be designed such that respondents answer statements or questions in writing. Designing a questionnaire requires skill and care and the way it is designed will affect the responses that will be given by respondents (Muijs, 2004:45).

A questionnaire has numerous advantages, and this played a role in it being chosen for the study. Some of the advantages are the following:

- It is cost effective as it can be delivered directly to participants and may require less time to distribute;
- It has a high assurance of anonymity and confidentiality;
- It is convenient; respondents can complete it at they own time giving them time to think about answers (Muijs, 2004:41);
- It can cover wide range of topics (Muijs, 2004:60);
- It can be used to collect data from large sample in a shorter period;
- Most users are familiar with questionnaires (Wilson & Sapsford, 2006:93); and

- A questionnaire yields a lot of information at a reasonable cost in time and effort (Vogt, 2007:90).

It can be easily distributed to a geographically scattered population and can be cheaper to collect data. In a questionnaire, people can respond to questions with assurance that their responses will be anonymous and they may be more truthful than they would be in a personal interview particularly when talking about controversial issues (Bell, 1993:197).

The designing of the questionnaire was guided by the following guidelines as outlined in Muijs (2004:50-51); Cohen et al., (2000:248-249 & 261); and McMillan and Schumacher (2001:258-260):

- It must be short and brief as possible;
- The questions must be simple, clear and short;
- Avoid double negative and double-barrelled questions;
- Ask one thing at a time;
- Strive to be unambiguous;
- Ensure that the respondent knows how to enter a response to each question;
- The questions must match the research objectives (Johnson & Christensen, 2004:165);
- Avoid leading questions that suggest to respondents that there is only one acceptable answer;
- Avoid using words, phrases that are ambiguous;
- Determine the type of questions you will use (Open-ended or closed-ended) (Johnson & Christensen, 2004:168); and
- Design a questionnaire that will be easy for the participants to use (Johnson & Christensen, 2004:176).

The criteria were considered when designing the questionnaire

3.3.4 The Design of the Questionnaire

The questionnaire was compiled after extensive literature review of relevant and related sources. A rating scale (Likert scale) was used in the study. Rating scales allow the respondents to choose on of the several options indicating level of agreement (McMillan & Schumacher, 2001:170). A rating scale is regarded as useful when behaviour, attitude or other phenomenon of interest to the researcher can be evaluated on a continuum. A scale larger than five makes it difficult for respondents to make distinctions of their choice (Muijs 2004:47-48), hence a five-point scale was used to help respondents make fine distinctions.

Muijs (2004:47) indicated that the inclusion of a middle category in questionnaires has caused confusions at times. Respondents who do not understand the question or who do not have an opinion choose the middle score. However, some respondents genuinely choose the middle score and it was this latest reason that resulted in the inclusion of the middle score in the questionnaire.

The questionnaire had two parts. The first part contains background information relevant to the study. Some of the background information included in the questionnaire was:

- The subject an educator is teaching;
- Experience in teaching the subject;
- Qualifications they poses;
- Time available for teaching the subject;
- Duration of training educators received from the department and other stake holders;
- Their feeling about the quality of in-service training they received in teaching scientific investigations; and
- The size of groups used in teaching scientific investigation.

The second part of the questionnaire consisted of twenty one closed-ended questions and one open-ended question. Open-ended questions have an advantage of allowing the respondents to freely formulate an answer (Cohen et al., 2000:248; and Muijs, 2004:46).

The researcher has an opportunity to discover answers or opinions that s/he never thought about before (Muijs, 2004:46; and Swift, 2006:159). Open-ended questions can be reduced to numerical score in the same way as the questionnaire item for interpretation (Swift, 2006:159).

The disadvantage of open-ended questions have a tendency of being more time consuming for respondents and for the researcher to code and quantify data (Muijs, 2004:46). Respondents would, as a result, be more disinclined to answer this type of questions (Muijs, 2004:46). The questions can also be difficult to code and analyse. For this study, one open-ended question and the other were closed ended questions.

Closed questions specify a task and range of possible responses to it. The respondents are forced to choose from one of the set of numbered options (Swift, 2006:159). Close-ended questions can generate frequencies of response amendable to statistical treatment and analysis (Cohen et al., 2000:247). Comparison can be made between groups in the sample. These types of questions are quick to complete and straight forward to code (Cohen et al., 2000:248).

Part two of the questionnaire was designed to collect data to answer the research questions as stated in 1.2.1. The following were the main focus of the study:

- Teaching methodology used by educators in teaching scientific investigation;
- The teaching methodology educators believe is the best for teaching scientific investigations through inquiry;
- Factors hampering the ability of educators to teach scientific investigations; and
- Feeling of educators about the in-service training they receive for preparing them to teach scientific investigations through inquiry

3.3.4.1 Teaching methodology

Teaching methodology used by educators in teaching scientific investigation teaching which are open inquiry, guided inquiry and structured inquiry. A Likert rating scale, as indicated below, was used for each statement in the questionnaires and respondents were requested to indicate their level of agreement by writing their option on the provided space. The total scores of each statement contributed to the overall score of a particular variable.

1	2	3	4	5
Always	Often	Sometimes	Rarely	Never

For Statements v31 and v33, the rating scale used is given below. Respondents were to choose their level of agreement by writing their option on the provided space.

1	2	3	4	5
Strongly agree	Agree	undecided	disagree	strongly disagree

The statements as indicated in the table below were used to collect data on teaching methodology described in this study.

Variable	Statement
Open inquiry	v15, v18, v27 and v30
Guided inquiry	v16, v17, v19, v28, v31 and v33
Structured inquiry	v14, v20, v24, v25 and v26

3.3.4.2 Best teaching methodology

Statement v35 was used to collect data on the methodology educators feel is the best for teaching scientific investigation through inquiry. There were three options and each statement represented the three types of teaching methodologies. Educators were to choose one of the following statements:

- Allow learners to bring their own questions and / or problems to be investigated;
- Use activities derived from text books; and
- Giving learners manuals to guide them step by step as they experiment/conduct scientific investigations.

3.3.4.3 Factors that hamper teaching through inquiry

In Statements v36 and v37, respondents were asked to rank two factors that hamper their ability to teach scientific investigations through inquiry. Six statements were provided and educators were to rank two factors that are most likely to impact on their ability to teach through inquiry. One was ranked first and the other second. The six statements are listed below:

- Poor learners science background;
- Use of a second language for teaching science;
- Time allocated to science;
- Insufficient in-service teacher workshop/retraining;
- Pressure to cover content; and
- Teacher workload.

3.3.4.4 In-service training

The questionnaire collected data, Statements v9 to v12, on the training respondents received that will help them teach through inquiry as outlined in the National Curriculum Statement. Respondents were to indicate the duration of training and how do they rate the training they received. Statement v29 collected data on how educators feel about their training they receive to teach through inquiry.

3.3.4.5 Teaching of scientific investigation and challenges faced by educators

One open-ended question was designing and educators were requested to describe how they teach scientific investigation and the challenges they face in teaching scientific investigations. Educators were also requested to indicate the way they assess scientific investigation inquiry activities.

3.4 VALIDITY AND RELIABILITY OF THE INSTRUMENT

It is important and essential to establish the reliability and validity of the research instrument used in a research. Reliability and validity are often discussed together but they are distinct (Vogt, 2007:113). The two are important of all research designs and measurement techniques.

3.4.1 Validity

Data collection instruments, such as questionnaires and interviews, are developed in quantitative research to measure variables that cannot be directly measured. An instrument used to collect data should be designed to measure what the researcher intends to measure. The results obtained using an instrument that does not measure what the researcher intends to measure such results will be meaningless (Muijs, 2004:65-66).

According to Vogt (2007:117), "validity refers to the truth or accuracy of the research". It refers to the relevance of the research instrument and the appropriateness of the interpretations made from test scores. McMillan and Schumacher (2001:239) describe validity as the extent to which inferences made on the basis of numerical scores are appropriate, meaningful and useful. Validity depends on the purpose of the study and the population in which it takes place.

Validity is improved through careful sampling, appropriate instrumentation and appropriate statistical treatments of the data. It is seen as a matter of degree rather than absolute state (Cohen et al., 2000:105). Content, construct and face validity are discussed in this study.

3.4.1.1 Content validity

Content validity refers to whether or not a content of the questions of a questionnaire is right to measure the concept that the researcher is trying to measure (Muijs, 2004:66). An instrument used to collect data must show that it fairly and comprehensively covers the items that it purports to measure (Cohen et al., 2000:109).

An extensive search of the literature on teaching of scientific investigations was undertaken to help to achieve content validity. It was design to address the topic under investigation in depth and breadth. Items used in the questionnaire are believed to be representative of what the questionnaire has to measure. The design of the questionnaire was influenced by the availability of time to answer it, as longer questions may reduce chances of the questionnaire to be completed (Muijs, 2004:46). Expert knowledge and pilot study was also used to validate the questionnaire.

3.4.1.2 Construct validity

Construct validity relates to the internal structure of an instrument and the concept it is measuring (Muijs, 2004:68). Construct validity is concerned with the question 'is the instrument measuring what one intends to measure' (Vogt, 2007:120).

It is related to the theoretical knowledge of the concept being measured and it is fostered by having a good definition and explanation of the meaning of the construct of interest (Johnson & Christensen, 2004:247). To ensure that the constructs were represented appropriately in the study, in-depth literature review was undertaken, the views of expects were used and the instrument was piloted before the actual study.

3.4.1.3. Face validity

Face validity is concerned with the degree to which the test appears to measure what it claims to measure (Vogt, 2007:120). It can be determined by asking individuals to inspect the items and decide whether the test seems to be valid. Vogt (2007:123) pointed out the importance of having an instrument to have face validity as mentioned below::

- Brings about higher levels of cooperation and motivation for the participants;
- Reduce feelings of dissatisfaction or injustice among low scorers;
- Help to convince participants to complete the instrument; and
- Help to improve public relations as non-experts can easily understand the relationship between the test and the characteristic it purportedly measures

  Piloting the questionnaire was also aimed checking the face validity.

3.4.2 Reliability

Reliability is concerned with precision and accuracy of an instrument (Cohen et al., 2000:117). It refers to consistency of either measurement or design in research (Vogt, 2007:114). It refers to the extent to which test scores are free of measurement error (Muijs, 2004:71). A Reliable instrument is regarded as reliable if it consistently produces similar results in similar conditions and when measuring the same construct. The instrument must yield similar data from similar respondents over time.

3.5 PILOT STUDY

Pilot test is a "preliminary test of a questionnaire" (Johnson & Christensen, 2004:177). It increases validity, reliability and practicability of a questionnaire (Cohen et al., 2000:260). There are several reasons that have been outlined by Cohen et al., (2000:260); Wilson and Sapsford (2006:103-104); and McMillan and Schumacher (2001:185) for piloting a questionnaire before the initial study is conducted, and some of the reasons are listed below:

- To check the clarity of the questionnaire;
- To gain feedback on the validity of the questionnaire and the purpose of the research;
- To eliminate ambiguity or difficulties in wording;
- To gain feedback on appropriateness of questions;
- To gain feedback on the layout of the questionnaire;
- To check the time taken to complete a questionnaire; and
- To identify commonly misunderstood or non-complete items.

During the pilot study, the questionnaire was distributed to three Natural Science educators and three Life Science educators. The educators were requested to comment on the time they take to complete the questionnaire, if there were questions that were not clear (ambiguous) and difficult to answer, as well as the colour of the (paper) used for the questionnaire.

The initial questionnaire had five open-ended questions. Only one educator completed all the open-ended questions. When all participants were requested to comment on the problem they encountered with the open-ended questions, they said that it took time to complete and they have too much work to do. To increase validity of the questionnaire, an analysis of the responses was made and it resulted in restructuring the questionnaire. At the end, four of the initial five open-ended questions were removed. Some questions (close-ended questions) were reworded as they were too ambiguous.

3.6 DATA COLLECTION

Data collection involves gathering of information about the variables in a study (McMillan & Schumacher, 2001:180). It is a vehicle through which researchers collect information to answer their research questions and base their explanations on the data collected. There are different methods used by educational researchers to collect data, viz., tests, interviews, questionnaires, observation and focus group (Johnson & Christensen, 2004:162).

Questionnaires were sent to all schools of the sampled clusters. If the population is smaller, a large percentage of the population must be selected (Johnson & Christensen, 2004:217), hence the questionnaire was sent to all schools in the two clusters. Questionnaires were sent to either Natural Science or Life Science educators of the two clusters. One questionnaire was sent to a school and it was either given to a natural science or life science educator.

Permission was granted by the senior district manager to conduct the study. An arrangement was made with Circuit Offices for the distribution and collection of the questionnaire. The questionnaires were sent to school through the circuit office and educators were to complete the questionnaire and submit to the principal who in turn had to send them back to the circuit office where they were collected.

Telephone conversation was made to schools that failed to return questionnaires. The present researcher made follow-ups to ensure that the questionnaires reach schools. When follow ups were made for the unreturned questionnaires, the following are some of the responses received:

- ☞ Educators lost/misplaced them before returning to the principal;
- ☞ The principal could not establish where they had put the questionnaire, and others said that educators have too much work to do; and
- ☞ The delegated person (from the school) never delivered it to the teacher

Follow-up questionnaires were sent to schools that claimed that they either had not received copies or they had misplaced/lost them. Each questionnaire was accompanied by two letters. One letter was directed to a principal and the other to the educators completing the questionnaire. The letter to educators requested them to complete the questionnaire confidentially and anonymously. The principal was requested to assist in giving copies of the questionnaire to educators and collect them later and then send them using the enclosed envelop to the Circuit Office.

During the first week, 17% of the total distributed questionnaires were received. Each questionnaire was marked with a code and this code was used to identify schools that returned the questionnaire. This was useful when a follow up for the unreturned questionnaires was made (Bell, 1993:207).

The choice of the type of data collecting method is based on its ability to answer question under investigation. To gather data, quantitatively tests, questionnaires, interviews and, structured observations are commonly used (McMillan & Schumacher, 2001:180).

3.7 DATA PRESENTATION AND ANALYSIS

As indicated in 3.6 above, the region consists of 115 schools that offer Life and Natural Sciences. For the study, 75 questionnaires were distributed to the cluster sampled, which consisted of 33 schools. Each school received two sets of questionnaires: one for a

Natural Science educator and the other for Life Science educator. Thirty-eight questionnaires were returned, representing a response rate of 51%.

The data were analysed using descriptive statistics and inferential statistics. Descriptive statistics are used to summarise, organize and reduce large numbers of observations or make sense of a particular data (Johnson & Christensen, 2004:177). The following descriptive statistics, that is, frequencies, percentages and means, were used to analyse the data.

Inferential statistics are used to make inferences or predictions about the similarity of a sample to the population from which the sample is drawn (McMillan & Schumacher, 2001:207 and Calder & Sapsford, 2006:210). The researcher used the laws of probability to make inferences and draw statistical conclusions about populations based on the sampled data (Johnson & Christensen 2004:177).

Calder and Sapsford, (2006:215) identify two aspects of inferential statistics, namely, hypothesis testing and estimation of parameters from sample data. Inferential statistics depends on descriptive statistics used. The inferential statistics used in this study was one way ANOVA.

3.8 SUMMARY

The chapter focused on research design and methodology used in this study. A non-experimental quantitative study was conducted. Data were collected and analysed quantitatively. A cross-sectional survey study in Bushbuckridge region in Mpumalanga was employed to collected data quantitatively. The population was divided into clusters and a random selection of the sample was conducted. A questionnaire was designed, piloted and distributed to Life Science and Natural Science educators. The questionnaire consisted of twenty one closed-ended and one open-ended questions.

The next chapter discusses data presentation and analysis, as well as the validity and reliability of the questionnaire.

CHAPTER FOUR

DATA PRESENTATION AND ANALYSIS

4.1 INTRODUCTION

The orientation of this research was presented in Chapter one, and in Chapter two an in-depth literature review was presented. The research design and methodology were discussed in Chapter three. This chapter focuses on data presentation, analysis and hypothesis testing.

4.2 BIOGRAPHICAL INFORMATION OF EDUCATORS

The biographical information of educators obtained for the study is presented first and consist of the following information:

- Subject being taught by the educators;
- Teaching experience of the educators;
- Type of qualification they have that qualifies them to teach Life Science and/or Natural Science;
- The size of groups used in investigations classes; and
- Duration of in-service trained of educators by the department and other stake holders.

The graph (Figure 4.1) below provides information of educators who participated in the study.

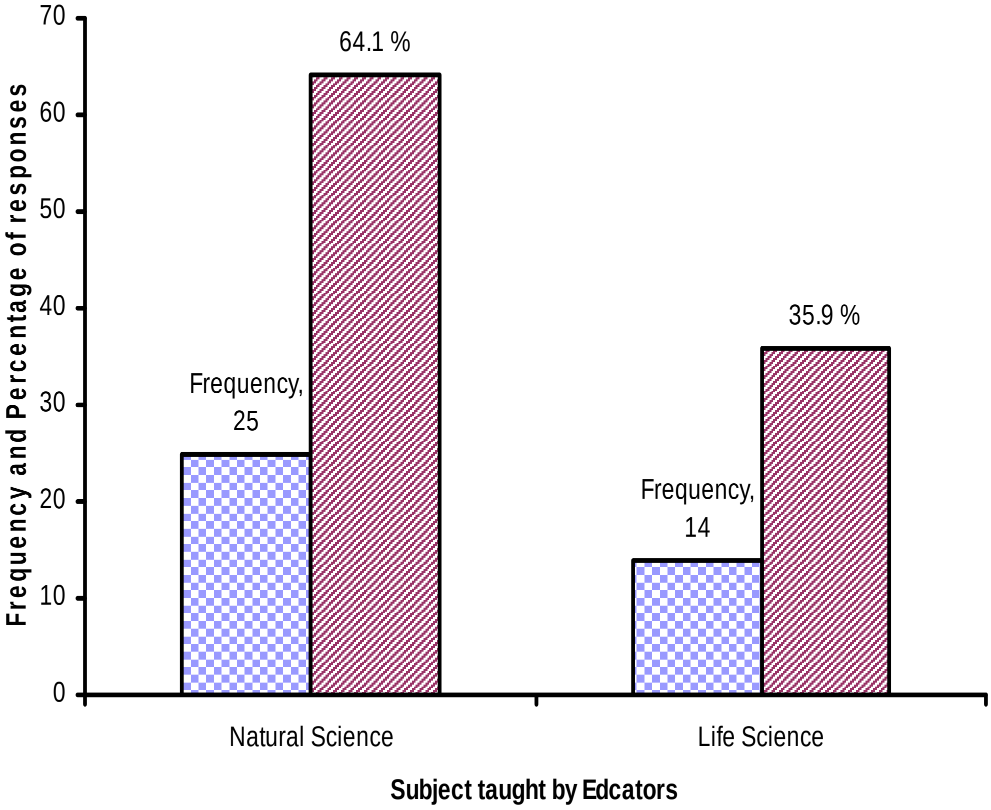


Figure 4.1: Percentage and frequency graph of participants

Educators were grouped according to the subject they teach, that is, Life Science and Natural Science. The graph, in Figure 4.1 above, indicates that 64.1% were Natural Science educators and 35.9% were Life Science educators. One educator teaches both subjects, viz., Life Sciences and Natural Science. Of the 64.1 % (Natural Science educators), 52% were teaching Grade 09, which is an exit point of the general education and training band and 48% were teaching Grade 08.

The graph in (Figure 4.2) below presents data on the teaching of experience of the Life Science and Natural Science educators.

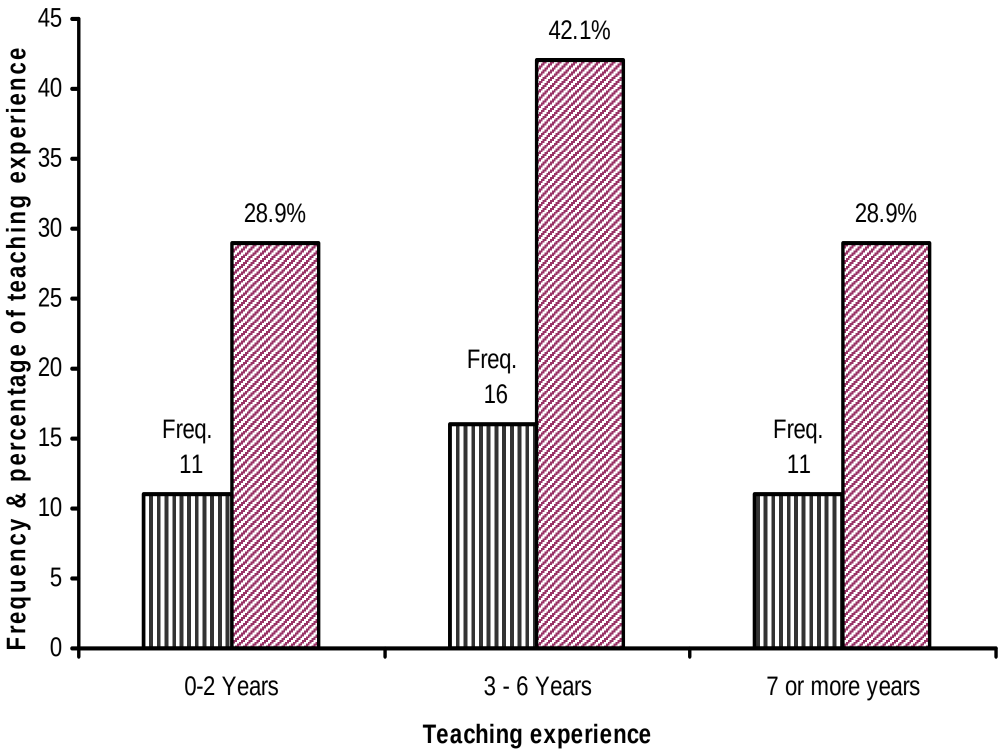


Figure 4.2: Teaching experience of educators

NB: Percentages might not add to 100% because of rounding off numbers.

Figure 4.2 above indicates the results of the distribution of educators in terms of their teaching experience in the two subjects. In this study, it was found that 28.9% of the educators have one to two years and seven or more years, respectively, of teaching experience and 42.1% of the educators have three to six years of teaching experience. The results show that more educators (71%) in the study were more experienced in teaching the subjects and only 28.9% has an experience of two years or less.

The graph in Figure 4.3 below indicates the qualifications of the educators teaching both Life and Natural Sciences.

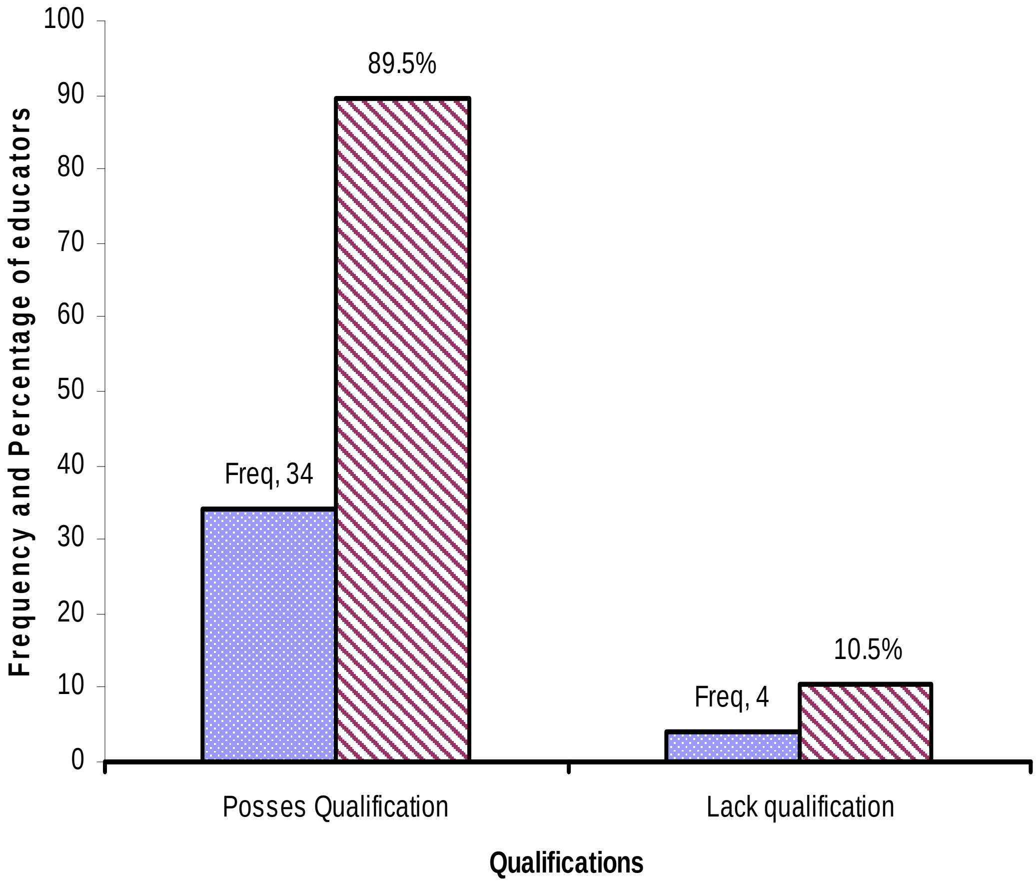


Figure 4.3: Educators' qualification

The graph, in Figure 4.3, indicates that 89.5% educators have a diploma or degree majoring in Biology (Botany and/or Zoology) and/or Physical Science. There are 10.5% the educators who are not professionally qualified to teach the two subjects. The information suggests that most of the participants (educators) have a tertiary qualification that qualifies them to teach the two subjects investigated in this study.

Below is a graph (Figure 4.4) indicating the number of learners used by educators in group investigations:

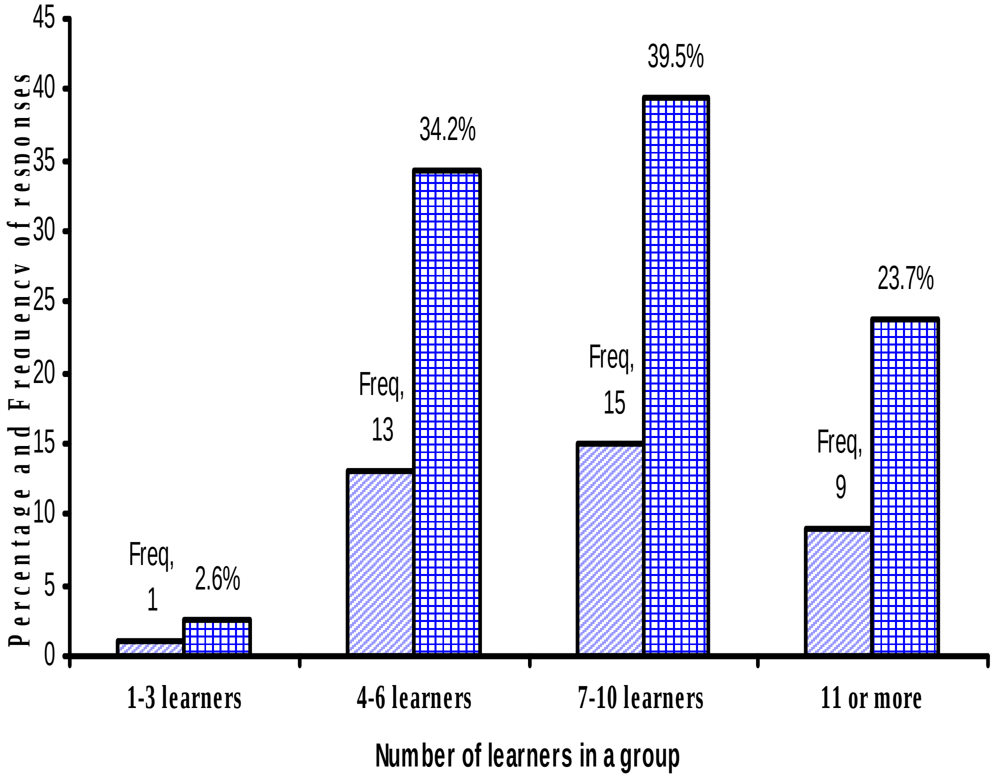


Figure 4.4: Number of learners used in a group when teaching scientific investigations

The size of groups used in teaching scientific investigations has a large impact on the outcome of learning. If the group is bigger, there is a greater likelihood that some of the learners will not actively participate during activities. As indicated in Figure 4.4 above, 36.8% uses a group of six learners or less, and 63.2% uses groups of seven learners or more during scientific investigations. The graph indicates that most educators use larger groups for group investigation.

The graph below (Figure 4.5) indicates the period educators received in-service training from the Department of Education which involves the teaching of scientific investigations.

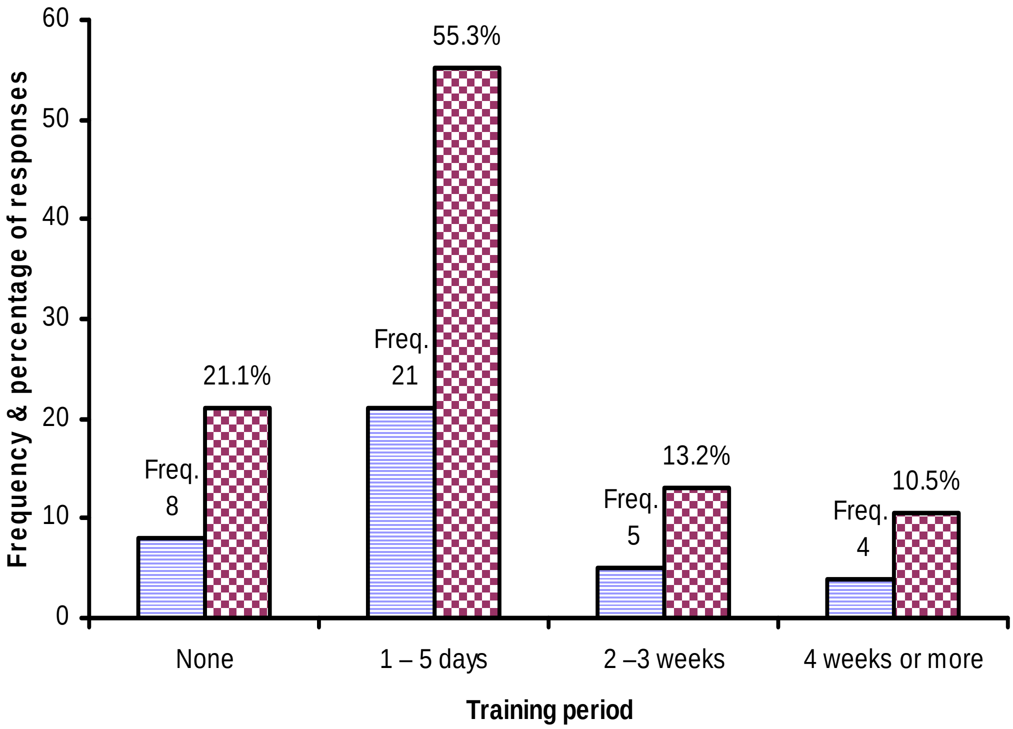


Figure 4.5: Duration of training of the educators to teach through inquiry

In-service training of educators is a strategy used by the Department of Education to help educators adapt to the changes relevant to education. It will provide educators with relevant skills and knowledge. Figure 4.5 above indicates that 21% of the participants (educators) never had any form of training related to the teaching through inquiry (new curriculum), 55% has a training of less than five days and 23% received a training of 2 weeks or more. The impact of the training will also depend on prior knowledge of the subject content and methodologies. Educators who have a qualification in Life Sciences and Natural Sciences have a better advantage to those who have no qualification in the subject.

The Figure 4.6 below describes the responses of educators on the in-service training they received from the Department of Education in enabling them to teach through inquiry method.

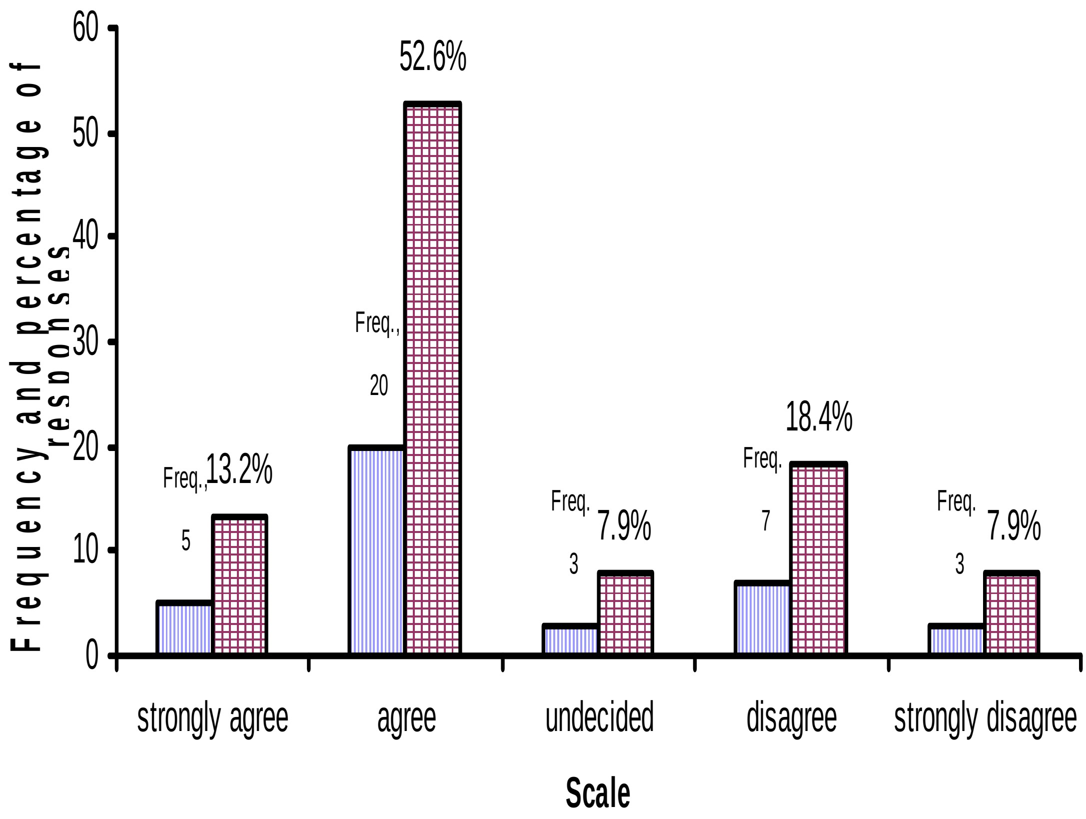


Figure 4.6: Responses of educators on training to teach through inquiry.

As indicated in Figure 4.6 above, 52.6% of the respondents agree, that they are properly trained to teach scientific investigations through inquiry. The figure shows that 13.2% stated that they strongly agree that they are properly trained. The study reveals that

26.3% of the educators disagree that they are properly trained to teach through inquiry instruction.

In Figure 4.7 and Figure 4.8 below, the graphs indicate how teachers raked certain factors which limit their ability to teach scientific investigation. Figure 4.7 indicates factors ranked first and Figure 4.8 indicates factors ranked second.

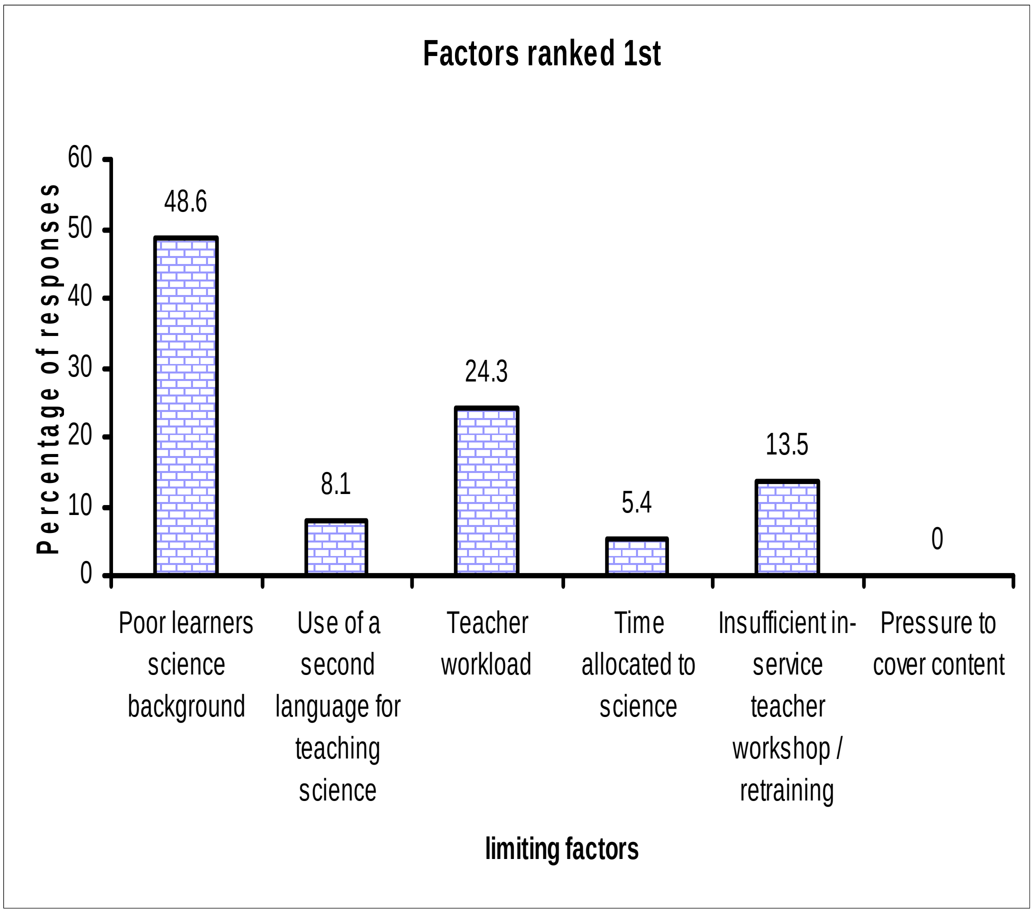


Figure 4.7: Ranked factors that hamper teaching of scientific investigations (ranked first)

From the data collected, as seen in Figure 4.7 above, 48.6% of the educators indicated that poor learners' science background is the major limiting factor and then teacher workload with 24.3 %. According to the information provided, pressure to cover content has minimal effect in limiting their ability to teach scientific investigations, thus there were no educators who indicated that pressure to cover content hamper their ability to teach scientific investigations.

In the graph below (Figure 4.8) are the results of the other factor that is limiting their ability to teach scientific investigations. Educators were to rank it as a second limiting factor.

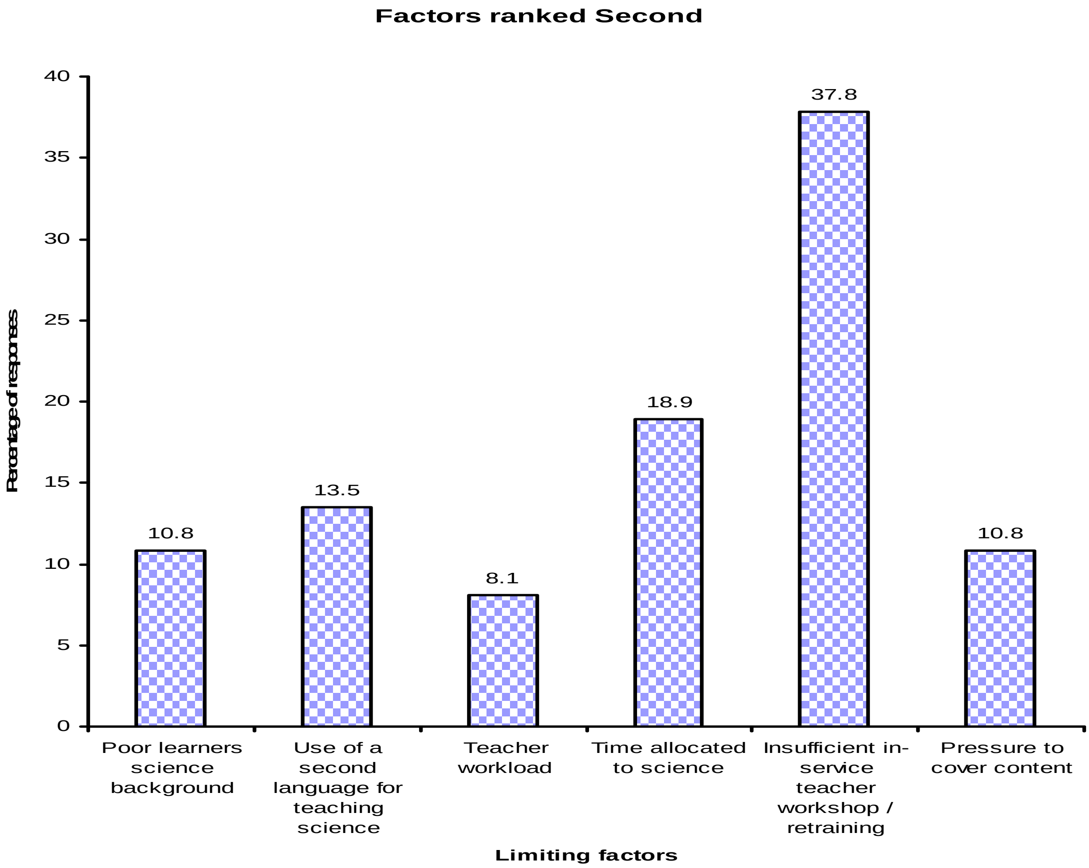


Figure 4.8: Ranked factors that hamper teaching of scientific investigations effectively (ranked second)

Educators, 37.8% felt that insufficient in-service teacher workshop is the major second limiting factor in their ability to teach scientific investigations. These results show that in-service training is still required to assist educators to understand what they need to do. The data show that there is no great distinction from the other factors in limiting the educ ators however, poor learners' science background and insufficient in-service teacher workshop/retraining, teacher workload also affects the teaching of scientific investigations.

In Table 4.1 below, the teaching methodology educators think is the best for teaching scientific investigations had been indicated.

Table 4.1: Teaching methodology for teaching scientific investigations

Variable	Frequency	% (Percentage)
Allow learners to bring their own questions and/or problems to be investigated	**4**	**10.5**
Use activities derived from text books	**9**	**23.7**
Giving learners manuals to guide them step by step as they experiment/conduct scientific investigations	**25**	**65.8**
Total	**38**	**100**

The table above shows that 65.8% of the educators think that the best method of teaching scientific investigation is giving learners manuals to guide them step by step as they conduct scientific investigations. There were 23.7% of the educators who felt that scientific investigations should be derived directly from textbooks.

The results given in the table indicate that only 10.5% of the respondents felt that allowing learners to bring their own questions and/or problems to be investigated was the best method for teaching scientific investigations. This shows that the majority of respondents felt this was not a viable approach.

The above findings may have been affected by the educators' views about time allocated to their subjects.

In the graph below (Figure 4.9) are the responses of educators about their view of the time allocated to their subject

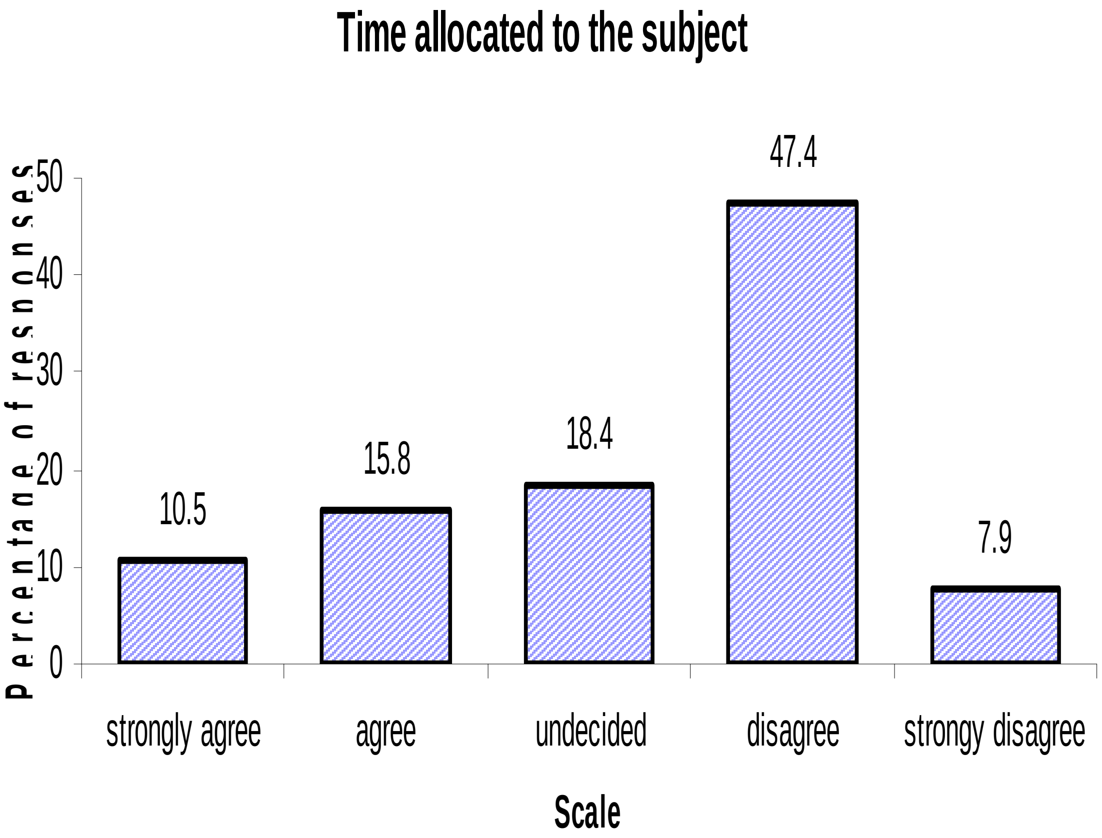


Figure 4.9: Time allocated to the Natural Sciences subject

The results mentioned above show that 26.3 % of the respondents indicated that it agrees that the time allocated to the teaching of scientific investigations is sufficient and 55.3% thinks that the time is not enough for them to teach scientific investigations. It can be seen that only 10.5 % of respondents agree strongly that enough time as been allocated to their subject. This might explain why a small percentage, also 10% in table 4.1 felt that allowing learners to bring their own questions and/or problems to be investigated was the best method for teaching scientific investigations.

4.3 INQUIRY TEACHING METHODOLOGY

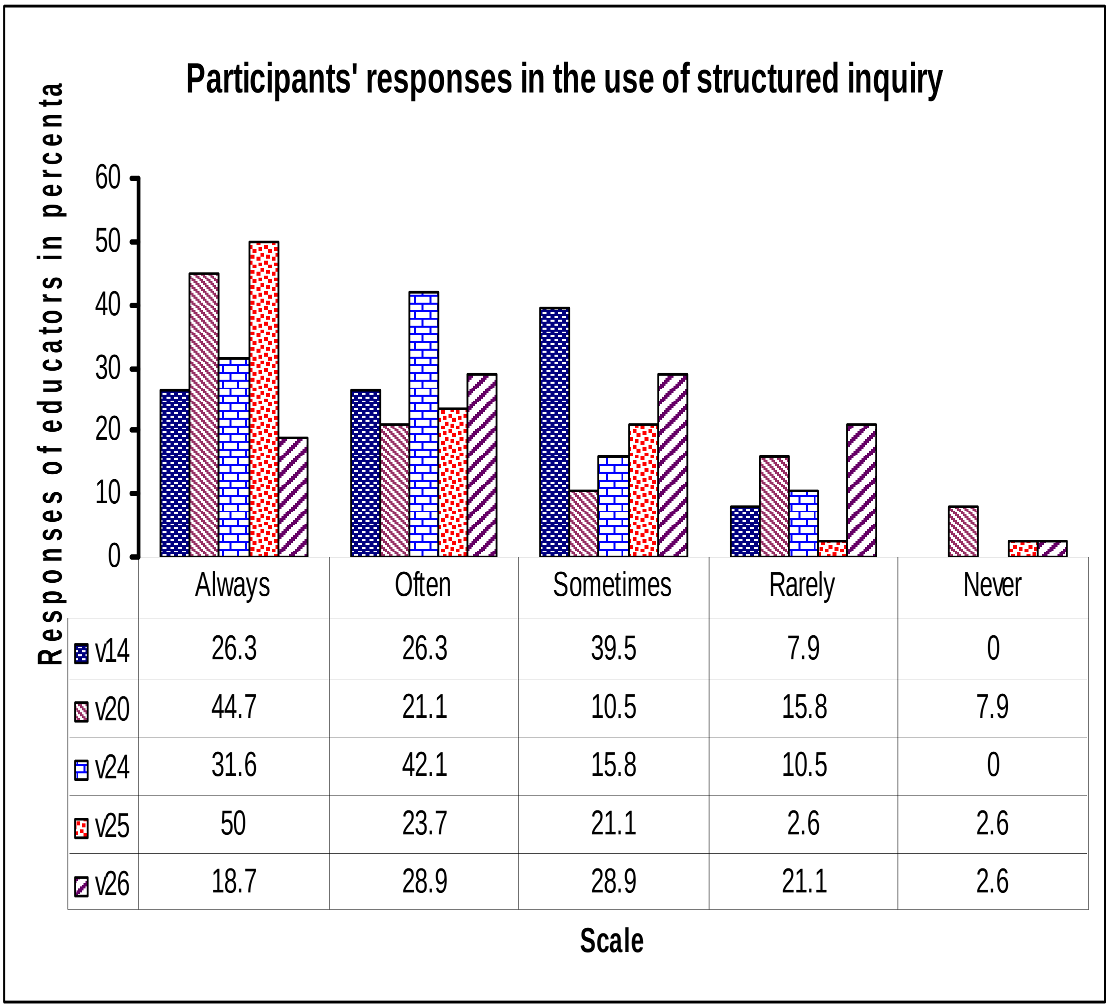
As indicated in Chapter two, there are three types of methodologies identified in this study and data were collected focusing on them, which are, namely, Structured inquiry, Open inquiry and Guided inquiry.

4.3.1 Structured Inquiry

Statements v14, v20, v24, v25 and v26 were used to collect data on this teaching methodology. All the statements were positively stated.

- ✱ V14: I derive investigation activities from text books.
- ✱ V20: I supply learners with manuals to follow during scientific investigations
- ✱ V24: I use investigations to verify facts taught in class
- ✱ V25: Experimental procedures are provided to learners by the teacher or textbook or manuals
- ✱ V26: Learners clarify or sharpen questions provided by a teacher or from other materials.

The results are summarised in Figure 4.10 below



	Always	Often	Sometimes	Rarely	Never
v14	26.3	26.3	39.5	7.9	0
v20	44.7	21.1	10.5	15.8	7.9
v24	31.6	42.1	15.8	10.5	0
v25	50	23.7	21.1	2.6	2.6
v26	18.7	28.9	28.9	21.1	2.6

Figure 4.10: Participants' responses towards the use of structured inquiry

Results of Statement v14 shows that 26.3% of the educators believe that activities for scientific investigation should be derived from textbooks and 39.5% said sometimes, activities should be derived from textbooks. There 7.9% educators who think activities should not be derived from textbooks. Statement v20 reveals that 65.8% of the educators believed that learners must be given manuals to guide them, which they should follow during the investigations and 7.9% indicated that they should never be given manuals.

Statement v24 shows that educators are more positive that scientific investigations should be used to verify facts taught in class. 31.6% of the educators indicated that scientific investigation should always be used to verify facts taught in class and 42.1% says it should be used often. Only 10.5% indicated that science should rarely be used to verify facts.

The results of Statement v25 show that 50% of the educators believe that experimental procedures should be provided to learners either by the teacher or from textbooks. This limits learners' creative ability to independently inquire and solve problems. 2.6% of the educators believed that learners should rarely and never give experimental procedures respectively.

Information collected with Statement v26 indicates that 47.6% of the educators believe that learners clarify or sharpen questions provided by a teacher or from other materials with 2.6% saying learners should learn scientific investigations by clarifying what educators or manuals provide them.

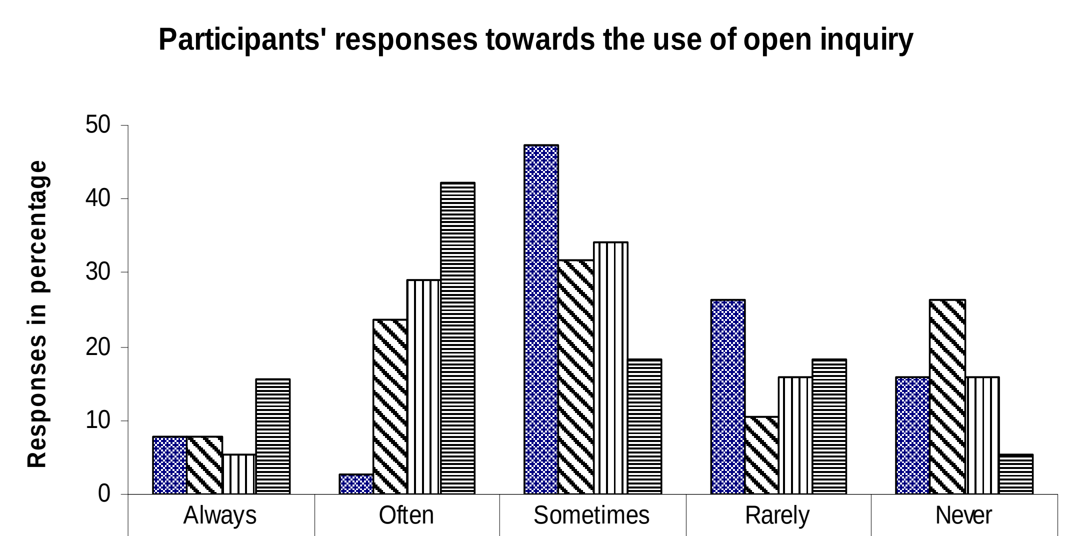
The results suggest that educators prefer and generally use structured inquiry in teaching scientific investigations.

4.3.2 Open Inquiry

Open inquiry is on the other extreme of structured inquiry (Figure 2.2). Information on this methodology was collected with four positively stated Statements v15, v18, v27 and v28. These statements are indicted below:

- ✱ V15: learners suggest questions and problems for investigative activities;
- ✱ V18: I allow learners to work without my intervention when conducting scientific investigations;
- ✱ V27: Learners plan and conduct investigations with minimal interference from the teacher; and
- ✱ V28: Learners work with the teacher on deciding how the investigations will be carried out.

The results are summarized in figure 4.11 below.



	Always	Often	Sometimes	Rarely	Never
v15	7.9	2.6	47.4	26.3	15.8
v18	7.9	23.7	31.6	10.5	26.3
v27	5.3	28.9	34.2	15.8	15.8
v28	15.6	42.1	18.4	18.4	5.3

Scale

Figure 4.11: Participants' responses towards the use of Open inquiry

Statement v15 reveals that 10.5% educators said that learners should be given opportunities to suggest questions and problems to be investigated. 15.8 % indicated that they must never be given opportunities to suggest questions and problems to be investigated. 26.3% indicated that this should be done rarely.

Statement v18 reveals that 26.3% of the educators support that learners should not work without the direct control of the educator. Some educators, 31.6% said that learners should work without the intervention of the educator.

Statement v27 reveals that 34.2% of the educators said that learners should plan and conduct investigations with minimal interference of the teacher and 31.6% said that learners should not plan and conduct investigations with minimal teacher interference.

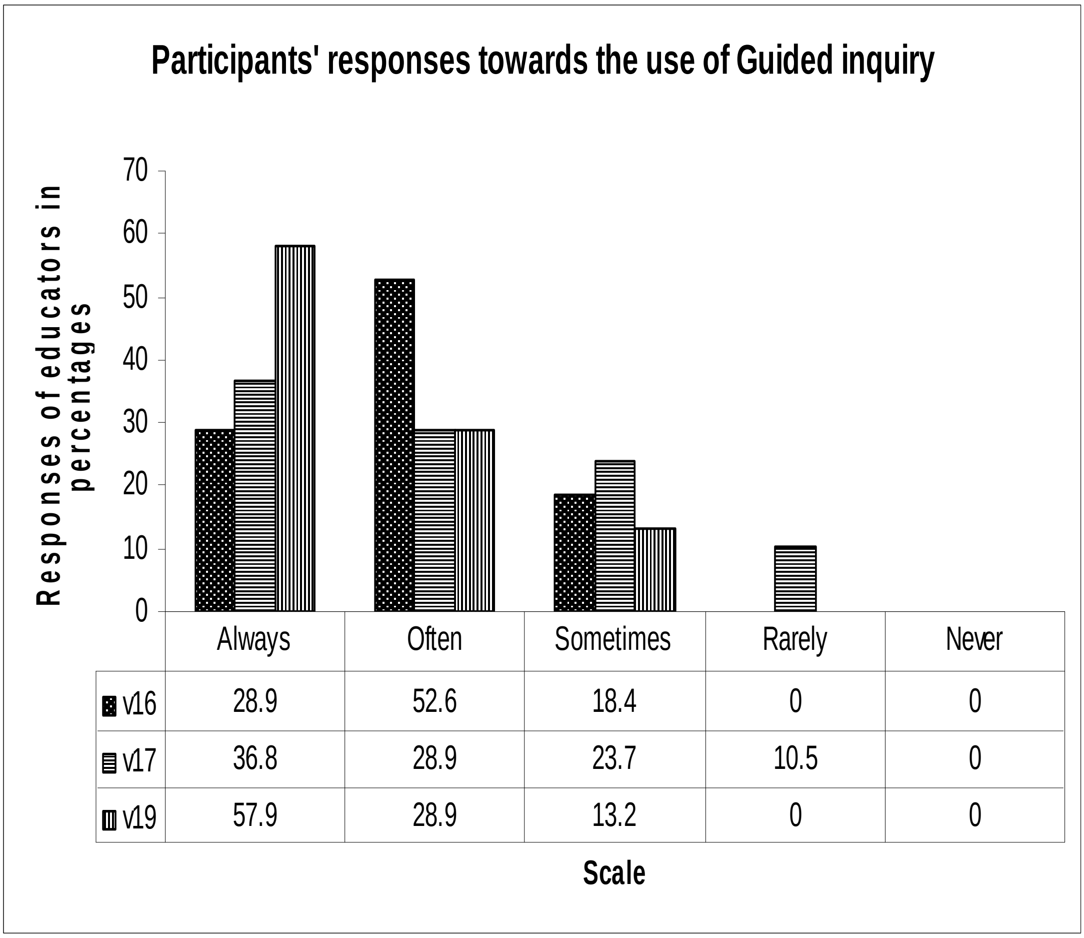
The last statement on the Table (v28) reveals that 57.7% educators indicated that learners should work with their teachers on deciding on how investigations should be carried out and 5.3% said that learners must never be involved on deciding on how investigations should be carried out.

4.3.3 Guided Inquiry

As outlined in Figure 2.2, Guided inquiry is an intermediate between Open and Guided inquiry. Statements v16, v17 and v19 were used to collect data on this type of inquiry. All the three questions were positively stated. Statements v31 and v33 were also used to collect data. These two Statements (v31 and v32) were also positively stated and the rating scale consisted of strongly agree, agree, undecided, disagree and strongly disagree. The statements are given below:

- ✱ V16: I provide learners with different possible questions to be investigated;
- ✱ V17: I design scientific investigation activities and guide them on what to do;
- ✱ V19: I guide learners as they are engaged in science investigation;
- ✱ V31: Learners need teacher intervention when learning scientific investigations; and
- ✱ V33: Learners must be given manuals that will guide them step by step during investigations

The results are presented in Figure 4.12 below.



	Always	Often	Sometimes	Rarely	Never
v16	28.9	52.6	18.4	0	0
v17	36.8	28.9	23.7	10.5	0
v19	57.9	28.9	13.2	0	0

Figure 4.12: Participants' responses towards the use of Guided inquiry

Educators generally indicated their preference of using Guided inquiry as indicated from the results in Figure 4.11 above. No educator was against the use of guided instruction. The results from Statements v16 (81.5%) v17 (65.7%) and v19 (86.8%) collectively indicate that educators generally support the use of guided instruction in teaching scientific investigations.

Figure 4.13 presents the responses of educators towards the use o guided inquiry

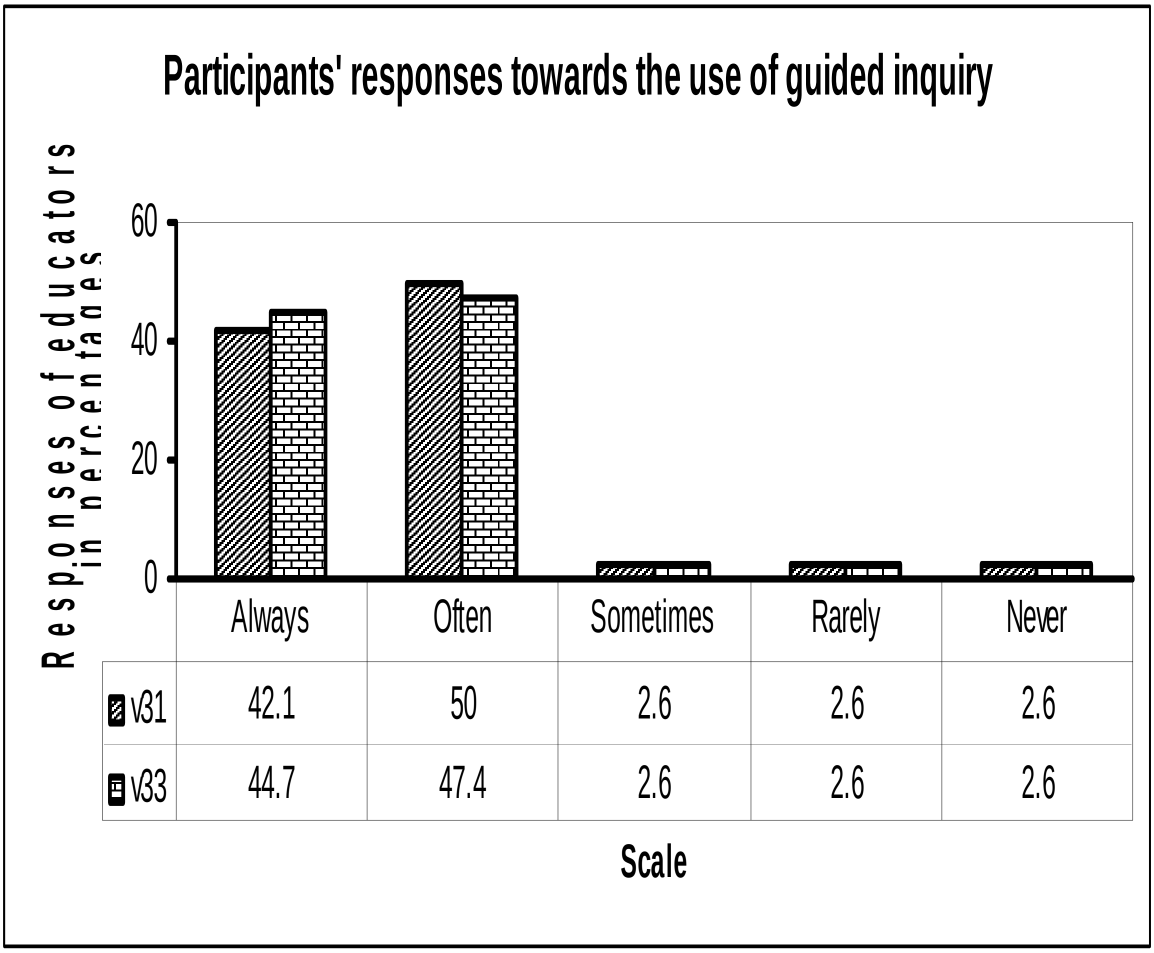


Figure 4.13: Participants' towards the use of guided inquiry

In Statement v31, educators were asked to respond to a statement stated "learners need teacher intervention when learning scientific investigations" and Statement v33 required educators to indicate their position about giving learners' manuals that will guide them step by step as they conduct scientific investigations. The results are outlined in Table 4.5 above.

For both statements, the results show that 92.1% of the educators agree that learners need manuals to guide them step by step and teacher intervention respectively during investigation activities. Only 5.2% of the educators disagree that learners should be given manuals.

4.4 OPEN-ENDED QUESTIONS

The questionnaire had open-ended question where educators were asked to rate how they teach scientific investigations. This question was not completed by all respondents; only 31 respondents completed this part. There was not enough depth in answering this section and the quantity of data was poor.

The first question dealt with teaching methods educators use for teaching scientific investigations and the second question was about the challenges they face in teaching and assessing scientific investigations.

The data were coded and clustered into two categories, and are described below. Johnson and Christensen (2004:502) describe coding as the process of marking segments of data with descriptive words.

4.4.1 Teaching of scientific investigations

Data collected from the educators have resulted in identifying two methods used by educators, namely, demonstrations and traditional cookbook inquiry. The results had been described below.

4.4.1.1 Demonstration

The description of educators on how they teach scientific investigations modelled demonstration method. Some educators indicated that most classes are overcrowded is carried out in groups scientific investigation. Learners are familiarised with apparatus, they show them how to conduct scientific investigation and teach them observation skills. Some educators indicated “after the experiment has been carried out learners should observe and tell the educator what did they observed”.

4.4.1.2 Use of traditional inquiry methodology

Educators indicated that they mainly derive activities from text book or past exam question papers as their main reference or design question or manuals to guide learners. Educators indicated that most experiments are discussed in a classroom with pictures drawn on the chalkboard.

4.5 CHALLENGES FACED IN TEACHING AND ASSESSING SCIENTIFIC INVESTIGATIONS

Educators were also asked to state challenges they face when teaching scientific investigations and, from the data, five factors were identified as challenges and such are discussed below.

4.5.1 Overcrowding

Some educators indicated that they have overcrowded classrooms hence grouping of learners into smaller groups is difficult. Educators use larger group, thus limiting the active participation of some learners during the duration of the activity. Under these conditions, learners have limited opportunities to learn to be inquirers and effectively work as team members, contrary to the developmental outcomes stated in the national curriculum statement.

4.5.2 Lack of resources

The researcher has observed that in most schools there are no special classroom or laboratory; no laboratory equipments; no additional reading materials; and there is a shortage of furniture. This makes the teaching of scientific investigation under these conditions difficult if they are to use open inquiry activities.

4.5.3 Language barrier

Educators indicated that the use of English as a medium of instruction (second language) is a problem to learners (Figure 4.8). These learners tend to have a limited ability in reading and understanding material written in English, this is also worsen by technical words encountered in science.

4.5.4 Teacher workload

Educators indicated that they have a heavy workload (Figure 4.7) and it is difficult to plan and give learners appropriate scientific investigation activities. The type of workload was not specified. Teachers' workload ranges from core curricular activities to administrative and extra curricula activities allocated to them and as part of developmental outcome to gain scores for salary adjustment.

4.5.5 Insufficient in-service training

The researcher felt that insufficient in-service training posses a major threat to educators. Quality and quantity in-service training can play a great role in imparting more knowledge in the classroom for implementing scientific investigations.

4.5.6 Time allocated to science

Teaching inquiry activities requires experience, effort and sufficient time for both educators and learners. Some educators indicted that they do not have enough time allocated to them to teach scientific investigations. Time allocation to teaching scientific investigation can be limited by the arrangement of the timetable.

4.6 HYPOTHESIS TESTING

Alternative hypotheses were tested in this study between selected biographical information and inquiry instruction. The alternative hypothesis was tested at 5% significance level. A null hypothesis cannot be rejected if $p > 0.05$ (Johnson & Christensen 2004:479). A statistical analysis method called Analyse-it + General 1.73 was used to analyse data for this study. One way analysis of variance (ANOVA) was used to compare the group means (Johnson & Christensen, 2004:478) and to calculate the f value.

HYPOTHESIS I: There is no significant difference between the choice of Inquiry instruction and Life and Natural Sciences educators

The table below presents data on the mean, the difference between the two means (teaching Life Science and Natural Science), the f value and p value that were used to test hypothesis I.

Table 4.2: F values and probability values of inquiry instruction and subject taught by educator

Subject teaching (v2)	Mean	Difference Between means	F value	p value
Teaching natural science	2.326	0.067	0.40	0.528
Teaching life science	2.258			

$p = 0.528 > 0.05$

Table 4.2 shows that the calculated p value is greater than the significant value at 0.05. The null hypothesis cannot be rejected. Therefore, there is no significant difference between Natural Science and Life Science educators in their choice of inquiry instruction method.

HYPOTHESIS II: There is no significant difference between the choice of Inquiry instruction and experience in teaching Life and Natural Sciences

Educators were classified into two groups; less experience and more experienced. Educators who have two or less in teaching the subject were classified as lesser experienced and those with three years or more were classified as more experienced. This classification was used for hypothesis II.

Table 4.3: f values and probability values of inquiry instruction and experience in life and natural science

Experience in teaching subject (v5)	Mean	Difference Between means	F value	p value
0 – 2 years teaching the subject	2.208	0.133	1.436	0.233
3 or more years teaching the subject	2.341			

p = 0.233 > 0.05

Table 4.3 shows that the calculated p value is greater than significant value at 0.05. The null hypothesis is therefore accepted and thus there is no so significant difference between lesser experienced and more experienced educators in teaching Life and Natural Sciences and the choice of inquiry instruction.

HYPOTHESIS III: There is no significant difference between the choice of Inquiry instruction and period of in-service training educators received from the department.

Educators were classified into two categories. There were educators who were trained by the department and those who never received any form of training from the Department of Education in preparation for the implementing of the curriculum, specifically for the subject studied (Life and Natural Sciences). Some educators were not trained for the subjects because of some of the following reasons:

- They were appointed after the formal training was over; and
- They received in-service trained to teach other subjects but because of subject allocation they were moved to subjects they were not trained to teach.

Table 4.4: f values and probability values of inquiry instruction and in-service training by the department of education

Period trained by the department (v9)	Mean	Difference Between means	F value	p value
Received no training	2.375	0.092	0.543	0.462
Received a training of one to five days	2.283			

p = 0.543 > 0.05

Table 4.4 shows that the calculated p value is greater than significant value at 0.05. The null hypothesis is, therefore, accepted and thus there is no so significant difference between educators who received departmental training and those who never received departmental period of in service training and the choice of inquiry instruction.

4.7 SUMMARY

This chapter focused on data presentation and hypotheses testing. The reliability and validity of the instrument used were discussed in the opening section. The study described the statistical techniques used to analyse the data collected from the sample. In the analysis of data, descriptive (frequency tables and graphs with percentages) and inferential statistics (Analysis of variance: ANOVA) were used.

A statistical software called Analyse-it + general 1.73 was used to calculate means, differences between means, f values and p values.

The results from the study suggest that most educators believe structured inquiry is the dominant method used to teach scientific investigations in Life and Natural Sciences classes. There is less preference in the choice of open inquiry method. The study found no significant relationship between experienced and less experienced educators in choosing inquiry instruction method. The study also found the there is no significant relationship between the training educators received and those who never received training, either from the department or other stake holders.

Educators indicated that their schools lack basic resources, they have overcrowded classes, they use demonstration method and their learners have a problem in using English as a medium of teaching science hence this affect their teaching of scientific investigations.

The study shows that a significant low percentage (i.e., 10.5%) of educators does not fully support open inquiry. In this case, educators need assistance with the orientation on inquiry and scientific investigations. Text books and activities in text books might not generate the same stimuli for learners; hence science activities should not always be derived on the same textbook. Educators should learn how to use different resources including internet which has extra information.

As indicated in Table 4.8, the difference between educators who received departmental training and those who received training is insignificant. Future training should have follow-ups to ensure that educators have understood what they were taught and are able to implement it in the classroom. Educators need further workshops on teaching scientific investigations. They should be able to move to higher levels when planning for activities.

In the next chapter, a discussion of the results is presented, as well as limitations, implication, recommendations and conclusion of the research.

CHAPTER FIVE

RESEARCH FINDINGS, LIMITATIONS, RECOMMENDATIONS AND CONCLUSIONS

5.1 INTRODUCTION

The purpose for conducting this study was to investigate how Life and Natural Sciences educators teach scientific investigations. This chapter focuses on the findings from literature review and findings from the study, limitations and recommendations.

Chapter two presented the literature review and Chapter one the orientation of this study. The research design and methodology were discussed in Chapter three and Chapter four discussed data presentation, analysis and hypothesis testing.

5.2 FINDINGS OF THE STUDY

This section presents result from literature review and data collected from educators.

5.2.1 Findings from literature review

Most of the sources used in this study were conducted by the international community, beyond the borders of the country, on both high school and beyond.

Review of literature revealed that the teaching of scientific investigations is not limited to laboratory practical activities only (Tamir et al., 1992). The National Curriculum Statement has been developed to an extent that the surrounding environment can be used as a tool to teach scientific investigations. This is a disadvantage to rural communities as they have limited environment for technological activities and stimulation. The study found that, through inquiry approaches, learners become active participants in the learning process.

The concept of scientific investigations has been used in this study synonymously to experimenting as the present researcher found no clear distinct differences between the two concepts from some sources consulted. Mbano (2004:105) described scientific investigations as tasks that require learners to plan and carry out an investigation and Rambuda (2003:95) described experimenting as an opportunity that provides learners with the ability to carry investigations and apply all process skills.

The study found that scientific investigations can be taught through inquiry approaches, and in a study by Suits (2004) it was found that learners gain significantly if they are taught scientific investigations through this approach. Inquiry can be applied using problem-based instruction and cooperative instruction. These two methods were found to be effective as a means of instruction.

In cooperative, learners activities are conducted in groups and this is useful as learners share their experiences, learn from one another and they can share limited equipments that are available. In an article by Lord (2001), it has been indicated that the benefits of using cooperative instruction outweighs the problems. A study by Greenwald (2000) indicated that using problem-based instruction in an inquiry class has resulted in significant improvement for learners and they tend to be more inquirers.

This study identified different levels and methods of inquiry used in teaching scientific investigations. The study found that shifting from structured (cookbook) to open inquiry has significant improvement on learning scientific investigations. Educators who use inquiry in their classroom have a greater likelihood that they can use it to other subjects other than science only (Rodgers, 2006).

Learning through inquiry should mean relinquishment of habits of passivity and dependence on teacher and textbook, in favour of an active learning. The lecture and textbook cease to be authoritative sources of information to be learned and become materials to be analyzed, teachers guide or assist them in ensuring that they do what they are expected to do in an investigation class, however they do not give them outright answers. Open inquiry allow learners to learn through experience, constructing their own meanings, make connections with the real world and see how science applies to them (Johnson, 2004:49). The outcome is not predetermined and the approach is student generated.

The role of educators in teaching scientific investigations has shifted from that of modelling an inquiry approach to supporting the students to design and implement their own inquiry-based investigations (Rodgers, 2006), the present researcher found no evidence of such shift in South African schools, because of limited research on the topic. Inquiry instruction does not mean that the educator is more passive, he/she is always there to guide and facilitate and the role changes according to the needs of learners.

Assessment of scientific investigations are not prescriptive and educators can use a variety of methods depending on the outcome of the activity and in this study baseline, formative, diagnostic and summative (as outlined in the National Curriculum Statement) (Department of Education, 2003) were discussed.

The study found that teaching scientific investigation is important because it tend to develop a positive attitude towards science, increases student achievement, students learn to be problem solvers, reduces dependence upon the teacher, improves students' abilities to apply scientific concepts and principles to different environment, students learn and understand the nature of scientific inquiry, help learners develop scientific skills of thinking invokes the intellectual skills and offers context and content for teaching science process skills.

Teaching scientific investigations through inquiry has its problems. De Jager and Ferreira (2003) stated that there is a need to provide resources in schools. In a study by Lazarowitz and Huppert (1993), they found that learners who used computer simulations in investigations showed significant improvements. Computers do not replace hands-on practical investigations, rather they are used as supplementary resources (Saat, 2004).

The study found that there is a need for stakeholders in the department of education from the school level to higher levels to work together, training and supporting educators with resources and knowledge skills to shift towards more open inquiry.

5.2.2 On answering the research question

The main question stated for the study was “how do life and natural educators teach the process skill of scientific investigations”. The research question was further divided into the three sub-questions stated below:

1. Which inquiry instructional methodology is used by life and natural science educators in the teaching of scientific investigations?
2. Do the experienced educators use more open inquiry than less experienced educators for teaching scientific investigations?
3. Was the in-service training offered to educators had an effect on the choice of inquiry instruction in teaching scientific investigations?

Based on the above questions, data were collected using a questionnaire. On the first question, the study found that most educators do not believe that open inquiry is the best method of teaching scientific investigations (section 4.3.2). As outlined in Roth and Roychoudhury (1993:141), learners are most likely to adjust to the expectations of their educators if the expectations of teachers are high, the same will be the same for learners. Educators do not have much confidence on the ability of learners to do open inquiry activities hence they will make less effort to set higher standards for these learners.

The study reveals that there are educators who prefer demonstrations and cookbook activities for teaching investigations more than open inquiry (section 4.4). The researcher believes that they might be limited by other factors associated with their teaching environment. Educators should be guided and supported to look beyond the formal laboratory setting as a means of teaching investigations.

In answering the question, the study found that educators prefer lower levels of inquiry (section 2.4) described by Roth and Roychoudury (1996) for teaching investigations (section 4.3 and Tables 4.10 to 4.13). On the second question, the study found that no significant difference between experienced educators and lesser experienced educators (section 4.6).

On the third question, the study found that educators believe that they are adequately trained during the in-service training programmes to teach scientific investigations through inquiry methodology (Figure 4.6). Their preference on cookbook activities and demonstrations (section 4.4) shows that there is no relationship to what they believe and what they apply in the classroom. This, however, reveals that educators have understanding inquiry but they do not use it in the science classroom and this cannot be associated with knowledge but other situation faced in the classroom environment, such as overcrowding and lack of resources.

On answering the main question for this study, it can be concluded that educators have enough knowledge to teach through inquiry instruction methodology however certain factors limit their ability to use them in the classroom situation hence they use the traditional (structured) inquiry more often.

5.3 LIMITATION OF THE STUDY

On reflection it is evident, from the researchers' viewpoint, the instrument was able to provide data for answering questions rose during the study, however, there is a need for more information in the area of teaching scientific investigation. Further studies can also focus on classroom observations and interviews to get more insight.

The result of the study was based on fifty one percent of the respondents who returned the questionnaires. The actual number of the educators participated in this study limited the statistical power for generalising the results to a wider population in the region.

The researcher in this study assumed that the questionnaires were completed sincerely and honesty, thus the results can be regarded as reliable and trustworthy.

For this study, data were collected from Grades eight and nine Natural Science; and Grade ten Life Science educators in the Bushbuckridge region, in Mpumalanga, hence generalisation of the results is limited to the region.

5.4 RECOMMENDATIONS FROM THE STUDY

The National Curriculum Statement is grounded on Outcomes-Based Education that also emphasises what learners can do. Educators in the science classroom should design activities that allow learners to guide their own learning (Johnson, 2004:48). Whilst educators are aware of the benefits of hands on activities, this is not reflected in practice (Palmer, 1997:73).

5.4.1 In-service training for educators

The study found that 21% of the educators never had an in-service training of the subject they are teaching and 55% had a training of five days or less (Figure 4.5). To promote quality and effectively teaching through the higher levels of inquiry requires that educators must have confidence in teaching the subject.

It is, therefore, recommended that in-service training of educators be continuously monitored and periodically implemented for all educators in the system. In-service training should also afford them to have practical experience on the subject. There is a need to promote professional teacher collaboration, from the school level up to the cluster level, with enough support from the school management, parents and the Department of Education.

5.4.2 Lack of infrastructure and equipments

Scientific investigations requires to a certain degree provision of resources to refer to and equipments that will cater for the learners. Lack of resources sometimes frustrates both educators and learners, hence learners might develop a negative attitude towards the sciences and thus few learners might opt out for these sciences in Grades10 to 12. The department must make provision of basic resources for teaching scientific investigations to all high schools this will make science more accessible.

5.4.3 Overcrowded classrooms

As stated in the study, most schools have overcrowded classrooms (section 4.5). This limits the ability to expose learners to as much activities as possible until they are familiar with more inquiry activities. Educators in turn use survival strategies. Rural schools are disadvantaged and are negatively affected.

5.4.4 Use of computer programmes

Today computers are advanced that programmes can be designed and used for teaching scientific investigations and cater for resources that cannot be easily accessible for most learners in class. Computer programmes have been identified by Moar and Fraser (1994) on an inquiry based Computer Assisted Learning environment that the programme are able to help students focus on problem solving techniques and promotes the development of inquiry skills. In schools where resources are not readily available and classes are overcrowded, computer simulations can be used.

It should be noted that computers do not replace laboratory experiments as stated by Lazarowitz and Huppert (1993:367), they must be used as a supplementary programme. The use of computer programmes requires that both educators and learners should be adequately trained, otherwise they will become useless for the system.

5.4.5 Access to researched documents.

Schools in rural communities do not have access to journal resources and other researched papers related to what they teach in their classrooms. These limit their ability to continuously have access to new developments in teaching from the country and abroad. The department should thus make some resources accessible to educators even to those who are not engaged to further training.

5.4.6 Further research

Most research in archives shows that there is little research that has been conducted in our schools on teaching process skills and scientific investigations in South African high schools. This calls for more research at school levels. A quantitative mode of inquiry was used in this study. The researcher thinks further studies are necessary wherein educators will be observed from the classroom to provide more insight in the field.

5.5 IMPLICATION OF THE STUDY

The study was to investigate the mode of inquiry instruction used by educators. The study reveals that students need to be engaged in doing science and educators should strive to move away from textbook driven (cookbook) instruction. Educators should have a distinction of simple laboratory activities and experimenting. Learners must be given an opportunity to be in the forefront of the learning process. Workshops on educators should also emphasise practical aspects of using open inquiry activities.

The study of the teaching of scientific investigation identified a gap between teaching practice and departmental expectations. Some educators still lack the basic knowledge of open inquiry instructional and how to implement the new curriculum in class. The department has to strengthen programmes to empower educators, mostly those in rural areas (where this study was investigated).

5.6 SUMMARY

Chapter one: the chapter provided an orientation that indicated a necessity to carry out the investigation on teaching scientific investigation through inquiry. The research question for the study, aim and significance of the study were stated. The concepts, scientific investigations, inquiry instruction and science process skills were introduced.

Chapter two: an in-depth literature review of science process skills, scientific investigations, teaching methodologies was done. Teaching methodologies identified are directed inquiry (traditional approach), guided inquiry and open inquiry. The different forms of assessing learners were briefly discussed as well as the role of the educator, problems affecting educators and the significance of teaching and learning through inquiry.

Chapter three: the research design and methodology were discussed. A quantitative non-experimental survey study was deemed appropriate for the topic investigated. A questionnaire was used to collect data from Life Science and Natural Science educators in the Bushbuckridge Region. A cluster sampling of four circuits of the thirteen found in the region was carried out. A pilot study and expert knowledge were used for validity and reliability of the questionnaire.

Chapter four presented research results that were analysed using descriptive statistics and analysed using a one way ANOVA. Challenges that were identified by educators are, namely, overcrowding, lack of resources, language barrier, teaching work load, insufficient in-service training and time allocated to teaching science.

5.7 CONCLUDING REMARKS

The study found that educators have knowledge of the inquiry instruction and the teaching of scientific investigations. Besides the knowledge of the methodology, inquiry instruction is rarely used in the science class. Teachers need motivation and support as it seems there are uncertainty of what to teach and how to teach through this method. Changing from the old system of teaching to the new methods is a concern for some educators.

Schools in rural communities where there are shortages of resources needs stimulant for both the educator and the leaner. In-service training methods should be used to monitor educators over a certain period and provide the necessary support where possible. Educators need also to have the confidence and willingness to change and accommodate changes and challenges of the modern age packaged in the curriculum. They need to understand the need to assist learners to be independent inquirers and thinkers. Learners should not always rely on the educator. There is a need for more classroom-based research in the South African context. Educators need opportunities for professional cooperation from cluster and school level in order to be professionally developed for the benefit of the learner and the country.

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Appendix A Questionnaire

QUESTIONNAIRE		V 1

- **Please complete the questionnaire anonymously**
- **Your participation is sincerely appreciated**
- **Indicate your response by writing the relevant number provided in the square on the right**

Background information

1. Subject teaching **1= natural Science** **2= Life Science**		V 2
2. Teaching experience **1= [0 – 4]** **2= [5 – 7]** **3= [8 –10]** **4 = [11 +]**		V 3
3. Grade teaching **1= Grade 08** **2=Grade 09** **3= Grade 10**		V 4
4. Experience in teaching subject **1= [0 –2]** **2=[3 – 6]** **3= [7 +]**		V 5
5. Qualification**: 1 =** Diploma or degree **with** Biology and / or physical science **2 =** Diploma or degree **without** Biology and / or physical science		V 6
6. Do you have an additional diploma or degree [Majoring in Science or Biology/Life science] **1 = Yes** **2 = No**		V 7
7. Minutes available per week for teaching science **1 = [60 – 120]** **2 = [121 – 150]** **3 = [151 – 180]** **4 = [181 +]**		V 8
8. Period trained by the department to implement new curriculum **1 = None** **2 = [1 – 5 days]** **3 = [2 – 3 weeks]** **4 = [4 weeks or more]**		V 9
9. How do you rate the training you received in preparing to teach scientific investigations? **1 = Excellent** **2. Very good** **3= Good** **4= Fair** **5 = Poor**		V 10
10. Period trained by other stakeholders other than the department of Education **1= Nome** **2= [1-5 Days]** **3= [2-3 Weeks]** **4 = [4 weeks or more]**		V 11
11. How do you rate the training you received in preparing to teach scientific investigations? **1 = Excellent** **2. Very good** **3= Good** **4= Fair** **5 = Poor**		V 12
12. The size of groups or number of learners (in class) when working cooperatively / in groups 1 = Excellent 2. Very good 3= Good 4= Fair 5 = Poor		V 13

Teaching Scientific Investigations

USE THE KEYS BELOW

1 = Always 2 = Often 3 = Sometimes 4 = Rarely 5 = Never

1. I derive investigation activities from text books		V14
2. Learners suggest questions and problems for investigation activities		V 15
3. I provide learners with different possible questions to be investigated		V 16
4. I design scientific investigation activities and guide them on what to do		V 17
5. I allow learners to work without my intervention when conducting scientific investigations		V 18
6. I guide learners as they when they are engaged to science investigation		V 19
7. I supply learners with manuals to follow during scientific investigations		V 20
8. I teach important concepts before learners can do scientific investigations		V 21
9. I make extra time to teach scientific investigations		V 22
10. I have some difficulty in using some laboratory equipments		V 23
11. I use investigations to verify facts taught in class		V 24
12. Experimental procedures are provided to learners by the teacher or text book or manuals		V 25
13. Learners clarify or sharpen questions provided by a teacher or from other materials		V 26
14. Learners plan and conduct investigations with minimal interference from the teacher		V 27
15. Learners work with the teacher on deciding how investigations will be carried out		V 28
USE THE FOLLOWING KEYS BELOW: **1 = Strongly agree 2 = Agree 3 = Undecided 4 = Disagree 5 = Strongly disagree**		
16. I am properly trained to teach scientific investigations		V 29
17. The cognitive level of learners is sufficient for conducting inquiry investigations		V 30
18. Learners need teacher intervention when learning scientific investigations		V 31
19. I have enough time allocated to natural science to teach scientific investigations		V 32
20. Learners must be given manuals which will guide them step by step during investigations		V 33
21. if you give your learners an investigative project. Rate their ability to do scientific investigation independently **1 = Excellent 2. Very good 3= Good 4= Fair 5 = Poor**		V 34

22. Which of the following do you **think** is the best method for teaching scientific investigations in your class?		
1. Allow learners to bring their own questions and / or problems to be investigated		V 35
2. Use activities derived from text books		
3. Giving manuals to guide them step by step as they experiment/conduct scientific investigations		

23. **Pick TWO** factors that you think hamper your ability to use inquiry to teach scientific investigations effectively		
1. Poor learners science background 2. Use of a second language for teaching science 1st 3. Teacher workload		V 36
4. Time allocated to science 5. Insufficient in-service workshop / retraining 2nd 6. Pressure to cover content		V 37

24. Can you describe how you teach and assess scientific investigations? You can also list the challenges you encounter in your class.		V 38

Appendix B: Letter sent to the Regional (district manager)

UNIVERSITY OF SOUTH AFRICA

INQ: Dr Nkopodi
Cell: 083 358 2317
Dlamini: 079 515 9911

University of South Africa
Pretoria
0003

The Regional Manager
Bushbuckridge Region
MPUMALANGA

REQUEST FOR A PERMISION TO CONDUCT A RESEARCH (DISSERTATION)

I am doing a research on natural science and life science teaching in our District with the University of South Africa

I therefore request your permission to distribute the questionnaires 9 copy attached) to secondary schools. The questionnaire will be solely used for my studies however a copy of the research report will be sent to your office as soon as it is available.

Thank you

____

Researcher (Dlamini AP)

Appendix C: Letter sent to the circuit manager

UNIVERSITY OF SOUTH AFRICA

INQ: Dr Nkopodi
Cell: 083 358 2317
Dlamini: 079 515 9911

University of South Africa
Pretoria
0003

The Circuit Manager

____

REQUEST FOR A PERMISION TO CONDUCT A RESEARCH (DISSERTATION)

I am doing a research on natural science and life science teaching in our District with the university of South Africa

I therefore request your permission to distribute the questionnaires (copy attached) to secondary schools. The questionnaire will be solely used for my studies however a copy of the research report will be sent to your office as soon as it is available.

Thank you

____

Researcher (Dlamini AP)

Appendix D: Letter sent to the School Manager (principal)

UNIVERSITY OF SOUTH AFRICA

INQ: Dr Nkopodi
Cell: 083 358 2317
Dlamini: 079 515 9911

University of South Africa
Pretoria
0003

The Principal (School manager)

____

REQUEST FOR A PERMISION TO CONDUCT A RESEARCH (DISSERTATION)

I am doing a research on natural science and life science teaching in our District with the university of South Africa

I am requesting your permission to distribute this questionnaire to your Natural science and Life Science educators. The questionnaire must be completed anonymously. I request you to collect the questionnaire from the educators and then send it back to the circuit office or an arrangement can be made to collect them from your institution.

Thank you for participating in the study

____

Researcher (Dlamini AP)

Appendix E: Letter sent to teachers

UNIVERSITY OF SOUTH AFRICA

INQ: Dr Nkopodi
Cell: 083 358 2317
Dlamini: 079 515 9911

University of South Africa
Pretoria
0003

Dear Science (Natural and Life science) educator

I am doing a research on natural science and life science teaching in our District with the university of South Africa

I therefore request your assistance in completing the questionnaire sincerely , anonymously and confidentially. The questionnaire must be submitted to your seniors (Principal) who will submit it to the circuit office immediately using the supplied envelop. You must seal the envelope as soon as you complete it to ensure confidentiality of the information.

PLEASE NOTE that all information collected from you will be treated in the strictest confidentiality and no educator' name or school will be mentioned in the research report.

I hope your will find the completion of the questionnaire as a unique experience.

Thank you for participating in the study

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Researcher (Dlamini AP)